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控制授粉對玉米臺農351號果穗及子粒生育性狀之影響[1]

曹紹徽　王強生　劉大江[2]

摘要　本試驗以單雜交玉米臺農351號爲材料，以套袋方式延遲授粉，縮短果穗上、下位子粒發育之時間差距，又限制穎花有效受粉時間，探討對玉米果穗不同部位子粒生育性狀及產量的影響。套袋延遲授粉有減少上位果穗不充實部份長度、增加穗周與提高上位子粒數及產量的作用，但中、下位子粒之百粒重有因而降低的趨勢，延遲授粉7日並顯著減少中、下位子粒之粒數與產量。經由控制有效授粉期可使果穗不同部位的子粒數目發生變異，如以對照植株之粒數爲準，自吐絲始期算起，上位穎花之受粉自第3日開始，9日內完成，與中、下位穎花分別於5及3日內完成受粉有顯著差異。果穗不同部位子粒之數目與平均百粒重間呈負相關，且上位子粒亦有充份發育的潛能。本試驗以控制授粉方式改變玉米果穗粒數及百粒重，發現不同部位子粒之間具有競爭作用，而縮短上、下位穎花受粉時間差距可增強上位子粒的相對競爭能力；經由確定穗內不同部位穎花有效受粉所需時間，認爲自雌穗吐絲始期開始，最少應有5日的花粉供應方可維持較高之子粒產量，可供爲品種選育及實際栽培時的參考。

關鍵詞：玉米、控制授粉、子粒充實、產量。

玉米子粒產量決定於光合成物質的生產能力與分配效率[12]，而供源與積儲均可能爲限制產量的因子[18]。依據曹等[5]之報告，單雜交玉米品種臺農351號於秋作在本省中部地區理想條件下栽培，生產光合成物質的供源能力超過果穗積儲對養分的需求；就玉米而言，積儲能力爲果穗子粒數目與平均粒重的乘積，而平均粒重的變異主要於子粒直線充實期間（linear kernel growth phase）決定[9]。子粒數目與平均粒重兩項因素中之任一項如果降低，產量都可能受到影響。

玉米果穗上位子粒的粒數、平均粒重及充實速率均不如中位及下位子粒[5]，Nishikawa and Kudo[15]認爲上位果穗的部份穎花雖能受粉與受精，但並不能充份發育，Tollenaar and Daynard[19]及林等[3]均指出上位子粒開始生長與發育的時間較中、下位子粒遲4至5日，王等[1]研究臺農351號穗頂充實不良的原因，發現果穗不同部位穎花之發育具有明顯的時序性差異，在利用養分方面，中、下位子粒可能對上位子粒產生強勢競爭或抑制作用，但林與劉[4]經由分析子粒充實期間穗位葉鞘與節間及穗軸的醣類組成與濃度，仍然證明光合成物質可充份轉移至穗軸頂端，並建議碳水化合物自玉米穗軸轉移至子粒的過程可能是決定上位子粒充實度的重要因子。

在另一方面，於玉米吐絲後將果穗以套袋方式延遲授粉數日，降低上、下位子粒發育之時序差異，有助於改善上位子粒的充實度[1]，顯示授粉時間對子粒發育確具作用，但是對中、下位子粒的發

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育及最終產量的影響猶待確定。本研究室曾以玉米臺農 351 號品種爲材料，進行多項與子粒充實特性有關之試驗，本項研究詳細探討延遲授粉及控制有效授粉時間對果穗不同部位子粒累積乾物質、氮素及碳水化合物模式的影響，本文僅涵蓋於成熟期測定果穗及子粒產量性狀的結果，有關重要組成分之累積速率將另文提出報告。

材料與方法

採用玉米單雜交種臺農351號（Tainung 351, TNG 351）爲材料，於1987年 8 月22日播種，在臺中縣霧峰鄉本所農場進行試驗，栽培之行株距均爲 80×20cm，合每公頃52,500株，播種時每穴播二粒種子，出土後間拔留一株，肥料用量及管理方法與林等 [3] 之報告相同。 本試驗分爲兩個項目 ，第一項爲以套袋方式延遲授粉處理，第二項爲控制有效授粉時間處理，兩項處理分別執行，均採完全逢機區集設計，重複四次，小區爲10行區，每行栽植41株。

延遲授粉處理的目的爲降低上、下位子粒發育之時序差異，係於玉米吐絲前以牛皮紙袋將大量果穗套袋，而後選擇同日開始吐絲之果穗，分別給予套袋 0（對照）、3、5、7 與 9 日處理；控制有效授粉時間處理的目的在瞭解不同部位子粒受粉所需時間，其方法爲選擇同日開始吐絲植株，分別於開始吐絲後 0、1、3、5、7 與 9 日套袋，亦即僅給予特定之授粉日數，而於吐絲後兩週除去套袋，令果穗充份發育。每一小區之上述每一控制授粉處理均包含至少30個果穗。

於玉米開始吐絲後25、42及69日進行取樣，每次自每小區選取 9 個果穗爲樣品，去除苞葉後利用送風乾燥箱以100°C處理2hr及 80°C 處理 48-72hr，予以烘乾。隨後測量穗頂未受精與不充實（含未受精）及果穗充實部份長度，再將果穗依長度均勻區分爲上、中及下三個部位，量度穗周、穗軸重、子粒數、百粒重及每穗粒重。各項數據均經變方分析，並以 Duncan's New Multiple Range Test 測定處理間之差異顯著性。

結　　果

套袋延遲授粉對玉米果穗長度及穗周的影響示於表 1；對照處理（不套袋）之全穗長爲21.08 cm，隨著套袋時間延長，穗長有逐漸增加的趨勢，例如套袋 9 日之穗長比對照處理增加11.5%。對照植株穗頂不充實部份的長度爲5.20 cm，相當於全穗長之24.7%，此一數值與比例亦因套袋延遲授粉而顯著降低，以套袋 7 日爲例，其不充實穗長僅爲2.30 cm，相當於全穗長之10.2%。不充實穗長中屬於未受精部份介於 2.05-3.71 cm，雖然也有因套袋而減短的趨向，但在多數處理間的效果並未達顯著水準，唯一之例外爲套袋 7 日處理，未受精長度較對照處理降低達44.7%。

對照植株上、中及下位穗周分別爲11.98、16.81 與 17.71 cm（表 1），套袋 3 及 5 日對中、下位穗周長度並無顯著影響，但 7 日與 9 日處理可使下位穗周減少 25.1 及 31.5%，中位穗周減少11.8及23.7%。相反的，套袋處理對增加上位穗周卻有顯著效應，例如套袋僅 3 日即可使上位穗周顯著增加10.2%。

在控制有效授粉日數的試驗方面，全穗長因授粉日數的減少而降低，僅給予 1 日授粉時間之穗長爲15.97 cm，較對照植株短24.2%（表 2），差異極爲顯著；授粉 7 日處理爲20.63 cm，與對照組已無差異，授粉 9 日處理之穗長反而大幅降低，其原因未明，可能爲試驗誤差所致。表 2 同時顯示，僅接受 1 日授粉果穗之全長雖大幅降低，但頂端不充實部位的長度卻達9.93 cm，顯示上位子粒發育嚴重受阻 ； 若延長授粉時間至 3 - 9 日，則不充實穗長與對照植株並無差異，或甚至有降低現象。授粉 1 日處理不充實穗長佔全穗長之比例高達62.2%，其他處理則介於17.4—25.8%之間。未受精部份穗長與不充實穗長之間有平行關係存在，有效授粉期 1 日之不充實穗長全爲未受精所致，隨授粉時間之增加，未受精部份所佔比例亦因而減少。

Table 1. Length and periphery of Tainung 351 maize ear measured at maturity as affected by various bagging durations for delay pollination*

Days of Bagging	Ear Length (cm)			Ear Periphery (cm)		
	Non-fertilized	Unfilled	Whole Ear	Upper	Middle	Lower
0	3.71 a (100.0%)	5.20 a (100.0%)	21.08 b (100.0%)	11.98 b (100.0%)	16.81 a (100.0%)	17.71 a (100.0%)
3	3.19 a (86.0%)	4.35 ab (83.7%)	21.35 b (101.3%)	13.20 ab (110.2%)	16.41 a (97.6%)	17.20 a (97.1%)
5	2.69 ab (72.5%)	3.31 bc (63.7%)	22.77 ab (108.0%)	14.05 a (117.3%)	16.35 a (97.3%)	16.49 a (93.1%)
7	2.05 b (55.3%)	2.30 c (44.2%)	22.50 ab (106.7%)	14.40 a (120.2%)	14.83 b (88.2%)	13.27 b (74.9%)
9	2.69 ab (72.5%)	2.69 c (51.7%)	23.51 a (111.5%)	12.89 ab (108.3%)	12.82 c (76.3%)	12.14 b (68.5%)

* Means with the same letter within each column are not significantly different at 5% leve l by Duncan's New Multiple Range Test. Figures in parentheses are percentages relative to control (0 day bagging treatment). Unfilled ear length includes nonfertilized portion.

Table 2. Length and periphery of Tainung 351 maize ear measured at maturity as affected by various durations of effective pollination*

Days of Effective Pollination	Ear Length (cm)			Ear Periphery (cm)		
	Non-fertilized	Unfilled	Whole Ear	Upper	Middle	Lower
CK	3.71 c (100.0%)	5.20 b (100.0%)	21.08 a (100.0%)	11.98 ab (100.0%)	16.81 a (100.0%)	17.71 a (100.0%)
1	9.93 a (267.7%)	9.93 a (191.0%)	15.97 c (75.8%)	6.33 d (52.8%)	8.80 d (52.4%)	11.60 e (65.5%)
3	4.59 b (123.7%)	4.65 b (89.4%)	18.05 b (85.6%)	8.92 c (74.5%)	15.75 b (93.7%)	16.94 b (95 7%)
5	2.32 d (62.5%)	3.01 c (57.9%)	17.28 b (82.0%)	11.79 b (98.4%)	15.32 bc (91.1%)	16.18 c (91.4%)
7	3.30 c (89.0%)	4.74 b (91.2%)	20.63 a (97.9%)	12.98 a (108.3%)	16.65 a (99.1%)	17.63 a (99.6%)
9	2.23 d (60.1%)	3.29 c (63.3%)	17.91 b (85.0%	11.63 b (97.1%)	14.71 c (87.5%)	15.56 d (87.9%)

* Means with the same letter within each column are not significantly different at 5% level by Duncan's New Multiple Range Test. Figures in parentheses are percentages relative to control (no restriction on pollination employed). Unfilled ear lngth includes nonfertilized portion.

穗周亦明顯受有效授粉時間的影響，授粉 1 日處理的上、中及下位穗周較對照處理減少 34.5—47.6%，授粉 3 日及 5 日處理亦有相同表現，但此一效應在授粉時間延長至 7 日時已不明顯（表 2），而授粉 9 日之穗周表現與其他處理之變化趨勢並不符合，可能爲試驗誤差所致，已敍述如前。限制授粉時間對果穗上位穗周的影響最大，授粉 1 日及 5 日時之降幅達47.2與25.5%，但授粉 5 日處理已未見明顯效應（表 2）。

套袋延遲授粉對與產量有關的子粒性狀表現之影響列於表 3 。對照處理植株每穗總粒數爲 621 粒

Table 3. Characrteistics of kernels grown on the upper, middle and lower portions of Tainung 351 maize ear as affected by various baging durations for delay pollination*

Days of Bagging	Kernel Number per Ear				100-Kernel-Weight (g)				Kernel Yield (g/ear)			
	Upper	Middle	Lower	Total	Upper	Middle	Lower	Total	Upper	Middle	Lower	Total
0	127 bc	266 a	228 a	621 a	12.15 c	25.76 a	28.05 a	23.92 a	15.43 c	68.52 a	63.95 a	147.90 a
	(20.5%)	(42.8%)	(36.7%)	(100.0%)	(50.8%)	(107.7%)	(117.3%)	(100.0%)	(10.4%)	(46.3%)	(43.2%)	(100.0%)
3	175 a	298 a	232 a	705 a	12.77 c	22.41 a	25.08 a	20.94 b	22.33abc	66.78 a	58.19 ab	147.32 a
	(24.8%)	(42.3%)	(32.9%)	(100.0%)	(61.0%)	(107.0%)	(119.8%)	(100.0%)	(15.2%)	(45.3%)	(39.5%)	(100.0%)
5	174 a	284 a	217 a	675 a	16.10 bc	22.62 a	23.75 a	21.31 b	28.01 ab	64.24 a	51.54 b	143.79 a
	(25.8%)	(42.1%)	(32.1%)	(100.0%)	(73.6%)	(106.2%)	(111.5%)	(100.0%)	(19.5%)	(44.7%)	(35.8%)	(100.0%)
7	151 ab	166 b	68 b	335 b	19.66 ab	23.87 a	24.85 a	22.46 a	29.69 a	39.62 b	16.90 c	86.21 b
	(39.2%)	(43.1%)	(17.7%)	(100.0%)	(87.5%)	(106.3%)	(110.6%)	(100.0%)	(34.4%)	(46.0%)	(19.6%)	(100.0%)
9	89 c	84 c	35 c	208 c	21.66 a	24.05 a	24.66 a	23.22 a	19.28abc	20.20 c	8.63 c	48.11 c
	(42.8%)	(40.4%)	(16.8%)	(100.0%)	(93.3%)	(103.6%)	(106.2%)	(100.0%)	(40.1%)	(42.0%)	(17.9%)	(100.0%)

* Means the same letter within each column are not significantly different at 5% level by Duncan's New Multiple Rangest.
Figures in percentages are percentages relative to individual total or mean valoes.

，其中上、中及下位粒數分別爲127（20.5%）、266（42.8%）及228（36.7%）粒；延遲授粉 3 日或 5 日對總粒數及各部位粒數並無顯著影響，但延遲授粉 7 日時，總粒數遽減爲 385 粒，其原因爲中、下位子粒數大幅降低，上位子粒數並不受影響，在這個例子中，上位子粒數佔總粒數的比例高達39.2%，中、下位所佔比例分別爲43.1與17.7%，顯示以下位子粒所受的影響最大；延遲授粉 9 日的表現又有過之，唯每穗上位子粒數目降低至89粒（表３），僅爲對照處理之70.1%，亦即吐絲時間較晚之上位穎花的受粉作用已嚴重受阻。

對照玉米植株果穗的平均百粒重爲23.92g，上、中及下位子粒的平均百粒重分別爲12.15、25.76及 28.05g（表３）；套袋延遲授粉雖似有降低中、下位子粒百粒重的趨勢，但在本試驗中的處理間差異均未達顯著水準；上位子粒之百粒重卻因而提高，尤其以延遲授粉 7 日與 9 日處理分別增加至19.66與 21.66g，效應最爲顯著。在每穗產量方面，套袋 3 日與 5 日與對照處理相同，均爲 145g 左右（表３），延遲授粉 7 日與 9 日則使產量大幅下降至86.21與48.11g。對照植株中、下位子粒的產量分別爲68.52 與 63.95g，佔一穗粒重之46.3與43.2%，此項數值與比例均因開始授粉時間之延後而下降，下位子粒所受影響尤爲顯著。上位子粒則有相反的表現，對照植株之粒重爲15.43g，僅佔總粒重之10.4%，顯示玉米產量主要由中、下位子粒所貢獻，但如延遲授粉 5 日，上位子粒粒重即增加至28.01g，佔總粒重之比例亦提升至19.5%，套袋處理 7 日的增幅更爲明顯（表３）。

有效授粉時間長短對子粒性狀的影響示於表 4；授粉 1 日處理植株之一穗總粒數僅爲50粒，不及對照處理（621粒）之 9 %；其中下位子粒（35粒）佔 70%，中位子粒（15粒）佔 30%，上位子粒數爲零。隨著有效授粉期之延長，各部位子粒數目均顯著增加，授粉 5 日處理的表現與對照已無顯著差異，但總粒數及中、下位粒數仍有偏低傾向。

縮短授粉時間雖使果穗粒數降低，但平均百粒重則大幅上升，例如授粉 1 日處理植株爲35.13g，其中中位子粒之百粒重高達 42.00g，下位子粒爲 31.17g，均極顯著超過對照處理（表４）。有效授粉期 5 日之平均百粒重性狀表現與對照之差異不顯著，但授粉 7 日之中，下位子粒百粒重高於對照，而授粉 9 日之下位子粒與全穗子粒百粒重却低於對照，與上述表現趨勢並不符合。在每穗粒重（產量）方面，授粉 1 日與 3 日分別爲17.56與124.41g，均低於對照之 147.90g（表４），授粉 5 日與 7 日之產量爲每穗140.18 及 152.97g，與對照相近，授粉 9 日反而降低至 125.23g，與趨勢並不一致。授粉 3 日處理之中，下位子粒產量與對照組已無顯著差異，上位子粒產量亦因授粉時間延長而提高，以有效授粉期爲 5 日以上之產量與對照相同。

討　　論

臺農 351 號玉米品種穗頂不充實的現象可能爲穗軸發育不良、穎花未受精及子粒不能充實等三種[1]，在本試驗中係以後二者爲主。玉米穗頂不充實的原因之一爲穗內子粒百育與充實的時序性差異（sequential difference), Bonnett[7] 指出玉米雌穗上穎花是由基部至頂端之方向（acropetal）分化，Frey[10] 認爲頂端穎花之發育最遲而最後受精，子粒開始充實的時間亦最晚。經由本試驗控制有效授粉期以改變果穗不同部位的子粒數目，發現自吐絲始期算起，上位子粒之受粉自第 3 日開始，9 日內完成，與中、下位分別於 5 及 3 日內完成授粉有顯著差異（表４）；而於吐絲始期行套袋處理，藉以縮短或消除上、下位穎花授粉時間的時序性差異，結果可大幅降低穗頂不充實長度及所佔總穗長之比例（表１），與王等[1] 的結論相同；延遲授粉 3 日與 5 日可顯著增加穗內上位子粒粒數，却不影響總粒數的表現（表３），顯示同一果穗內不同部位穎花或子粒間相互競爭的程度可能已被降低，將再詳細討論於後；此一推論並可由上位子粒的平均百粒重及產量均能被提高而得到支持，Bagnara and Daynard[6] 亦曾報告延遲授粉可使頂端三分之一部位粒重顯著增加。

上位子粒充實度不如中、下位子粒的另一個原因可能與光合成物質的供需平衡關係及養分需求競爭作用有關，就臺農 351 號品種而言，光合成物質的生產能力頗爲充裕，並無不足之慮，產量主要受

Table 4. Characteristics of kernels grown on the upper, middle and lower portations of Tainung 351 maize ear as affected by various duration of effective polliation*

Days of Effective Pollination	Kernel Number per Ear				100-Kernel-Weight (g)				Kernel Yield (g/ear)			
	Upper	Middle	Lower	Total	Upper	Middle	Lower	Total	Upper	Middle	Lower	Total
CK	127 b	266 a	228 a	621 a	12.15 b	25.76 c	28.05 b	23.92 c	15.43 ab	68.52 a	63.95 a	147.90 a
	(20.5%)	(42.8%)	(36.7%)	(100.0%)	(50.8%)	(107.7%)	(117.3%)	(100.0%)	(10.4%)	(46.3%)	(43.2%)	(100.0%)
1	0 d	15 c	35 c	50 c	0.00 c	42.00 a	32.17 a	35.13 a	0.00 c	6.30 c	11.26 c	17.56 c
	(0.0%)	(30.0%)	(70.0%)	(100.0%)	(0.0%)	(119.6%)	(91.6%)	(100.0%)	(0.0%)	(35.9%)	(64.1%)	(100.0%)
3	38 c	199 b	189 a	426 b	24.74 a	29.15 b	30.16 a	29.18 b	9.40 b	58.01 ab	57.00 ab	124.41 b
	(8.9%)	(46.7%)	(44.4%)	(100.0%)	(84.8%)	(99.9%)	(103.4%)	(100.0%)	(7.6%)	(46.6%)	(45.8%)	(100.0%)
5	136 b	245 a	204 a	585 a	15.52 b	25.74 c	27.46 b	24.03 c	21.11 a	63.06 ab	56.02 ab	140.18 a
	(23.3%)	(41.9%)	(34.8%)	(100.0%)	(64.6%)	(107.1%)	(114.3%)	(100.0%)	(15.1%)	(45.0%)	(40.0%)	(100.0%)
7	136 b	235 ab	204 a	575 a	14.76 b	29.01 b	31.73 a	26.64 c	20.07 a	68.17 a	64.73 a	152.97 a
	(23.7%)	(40.9%)	(35.5%)	(100.0%)	(55.4%)	(108.9%)	(119.1%)	(100.0%)	(13.1%)	(44.6%)	(42.3%)	(100.0%)
9	158 a	232 ab	215 a	605 a	11.39 b	23.55 c	24.46 c	20.74 d	18.00 a	54.64 b	52.59 b	125.23 b
	(26.1%)	(38.4%)	(35.5%)	(100.0%)	(54.9%)	(113.6%)	(117.9%)	(100.0%)	(14.4%)	(43.6%)	(42.0%)	(100.0%)

* Means the same letter within each column are not significantly different at 5% level by Duncan's New Multiple Rang Test.
Figures in percentages are percentages relative to individual total or mean values.

限於積儲容積[13]，而養分是否可充份自穗軸轉移至子粒則可能限制上位子粒之充實[4]；在養分競爭方面，Nishikawa and Kudo[15]指出穗頂部份穎花無法充份發育，這些穎花雖可受精，但子粒充實在早期即已停止，Poneleit and Egli[17]認爲上位子粒的積儲强度（sink strength）較弱，因此直線充實期之發生時間及充實速率均不如中、下位子粒；但另有報告建議玉米上位子粒之充實度固然不佳，却仍具有充份發育潛能 Hanft *etal.*[11]以*in vitro* 方式培養，發現上位子粒之發育可與下位子粒相同，Ou-Lee and Setter[16]提高玉米穗頂部位溫度，也有相同的結果。本試驗以套袋方式延遲授粉可增加上位子粒百粒重，尤以延遲授粉9日處理之百粒重高達 21.66g（表3），僅給予3日之有效授粉期處理更高達24.74g（表4），顯示上位子粒的充實能力頗高，粒重有再予提高的可能。

但在另一方面，本試驗套袋延遲授粉的部份處理雖然同時增加上位子粒數目與提高其平均百粒重，却降低了中、下位子粒的百粒重（表3），而隨著有效授粉期自3日延長至9日，上位子子粒數目逐漸增加（中、下位子粒亦同），百粒重亦明顯降低（表4），似乎又顯示不同部位子粒間對養分的强烈競爭，以及光合物質供源能力有所不足；不過本試驗曾於子粒充實期間取樣分析非構造性碳水化合物濃度，結果顯示不同部位穗軸在吐絲後42日的濃度均超過20%，而且對照與處理間的差異並不顯著（待發表資料），表示有充份的碳水化合物供應至穗軸部位，與林與劉[4]以相同材料在不同年度的試驗結果相同，因此推測養分自穗軸轉移至子粒爲影響充實度的重要機制所在；但基於下位子粒百粒重因延遲授粉而降低之事實，仍不能排除不同部位子粒間具有相互影響作用的可能性。

在授粉良好的條件下，玉米果穗上子粒排列緊密，相互間產生機械性限制，因而影響子粒充份發育；如果不改變一穗粒而欲提高百粒重及產量，就必需考慮子粒是否具有較大深（高）度的特性[2]；換言之，子粒平均百粒重可能與其生長空間有關。合併套袋延遲授粉及控制有效授粉日數兩項試驗數據（僅去除套袋9日處理），進行粒數與百粒重間的相關分析，發現上位與中位子粒部份的負相關分別達到5%與1%顯著水準（依序爲 $r=-0.870^{*}$與-0.890^{**}），而下位子粒的負相關達10%顯著水準（$r=-0.628$），可以提供部份證明；王等[1]即曾發現玉米臺農351號品種穗軸頂端部位可能發育不良而萎縮，是導致上位子粒充實欠佳的原因之一。

Dow *et al.*[8]與 Muleba *et al.*[14]認爲玉米抽穗與吐絲時間差距之長短與產量有密切關係，如果縮小此一差距，可增加結實粒數，並使上位粒重顯著升高[6]，本試驗採取套袋延遲授粉處理，使果穗上不同部位穎花在相近的時間授粉，結果發現經套袋3日及5日可大幅增加上位子粒的粒數與產量，不影響中、下位子粒粒數，但使其百粒重有降低趨勢（未達5%顯著水準），唯總粒數雖然增多，一穗總產量則維持不變（表3），顯示以套袋方式延後中、下位子粒授粉時間對其充實性可能有不利的影響，而人爲縮短抽穗與吐絲時間差距的實用意義猶待肯定。在另一項具有相對性作用的控制有效授粉日數處理中，則確定穗內不同部位穎花所需有效授粉期的長短及差距，認爲自雌穗吐絲始期開始，最少應有5日的花粉供應時間，方可維持較高的子粒產量，可以供爲今後品種選育及實際栽培時的參考。

引用文獻

1. 王强生、曹紹徽、劉大江。1985。玉米臺農351號穗頂不充實原因之探討。中華農業研究34：266—278。
2. 呂宗佳、謝光照、何千里、莊周瑞。1986。馬齒種與硬粒種玉米自交系雜種優勢及組合力之全互交分析。中華農業研究35：145—164。
3. 林淑雰、劉清、劉大江。1990。影響碳水化合物自玉米穗軸轉移至子粒因素之研究1.果穗上位與下位子粒之充實特性。中華農業研究39：29—37。
4. 林淑雰、劉大江。1990。影響碳水化合物自玉米穗軸轉移至子粒因素之研究2.子粒充實期間莖稈與穗軸醣類濃度的變化。中華農業研究39：38—46。
5. 曹紹徽、王强生、劉大江。1986。玉米子粒充實特性之研究。中華農業研究35：23—36。
6. Bagnara, D., and T. B. Daynard. 1982. Rate and duration of kernel growth in the determination

of maize (*Zea mays* L.) kernel size. Can. J. Plant Sci. 62 : 579-587.

7. Bonnett, O. T. 1960. Inflorescences of maize, wheat, rye, barley and oats: their initiation and development. III. Agri. Sta. Bull. 721.
8. Dow, E. W., T. B. Daynard, J. F. Muldoon, D. J. Baker, and G. W. Thurtell. 1984. Resistance to drought and density stress in Canadian and European maize (*Zea mays* L.) hybrids. Can. J. Plant Sci. 64 : 575-585.
9. Egharevba, P. N., R. D. Horrocks, and M. S. Zuber. 1979. Dry matter accumulation in maize in response to defoliation. Agron. J. 68 : 40-43.
10. Frey, N. M. 1981. Dry matter accumulation in kernels of maize. Crop Sci. 21 : 698-701.
11. Hanft, J. M., R. J. Jones, and A. B. Stumme. 1986. Dry matter accumulation and carbohydrate concentration patterns of field-grown and *in vitro* cultured maize kernels for the tip and middle ear positions. Crop Sci. 26 : 568-572.
12. Hofstra, G., and C. D. Nelson. 1969. The translocation of photosynthetically assimilated C-14 in corn. Can. J. Bot. 47 : 1435-1442.
13. Liu, D. J. 1987. Physiological and cultural studies of field corn grown on paddy field in Taiwan. In: Proceeding of Sino-Japan Symposium on Production Technology of Dryland Food Crops in Paddy Field (S. C. Hsieh and D. J. Liu, eds.). Taichung Dist. Agri. Improv. Sta., Changhua.
14. Muleba, N., T. G. Hart, and G. W. Paulsen. 1983. Physiological factors affecting maize (*Zea mays* L.) yields under tropical and temperate conditions. Trop. Agric. 60 : 3-11.
15. Nishikawa, H., and M. Kudo. 1973. Explicational studies on the sterile ear as appeared on mechanized cultivation of the corn plant (*Zea mays* L.). Thoku Agri. Exp. Sta. Res. Rep. 44 : 51-95.
16. Ou-Lee, T. M., and T. L. Setter. 1985. Effect of increased temperature in apical regions of maize ears on starch-synthesis enzymes and accumulation of sugars and starch. Plant Physiol. 79 : 852-855.
17. Poneleit, C. G., and D. B. Egli. 1979. kernel growth rate and duration in mare as affected by plant density and genotype. Crop Sci. 19 : 385-388.
18. Schoper, J. B., R. R. Johnson, and R. J. Lambert. 1982. Maize yield response to increased assimilate supply. Crop Sci. 22 : 1184-1189.
19. Tollenaar, M., and T. B. Daynard. 1978. Kernel growth and development at two positions on the ear of maize (*Zea mays*). Can. J. Plant Sci. 58 : 189-197.

Effect of Controlled Pollination on the Characteristics of Ear and Kernel Development of Tainung 351 Maize[1]

S. H. Tsao, C. S. Wang and D. J. Liu[2]

Summary

Two experiments, grain competition and silking sequence, were conducted by using the single-cross maize hybrid Tainung 351 as experimental material. For grain competition study, pollination was delayed by bagging the ear at silking to reduce the sequential difference in kernel development between kernels positioned at different positions of the ear. For silking sequence study, maize ears were allowed to pollinate for only limited periods of time. The purpose was to study the effect of controlled pollination on the ear and kernel characteristics at maturity. Delay pollination tended to reduce the length of unfilled portion at ear-tip, and to increase periphery of upper ear, and both number and yield of kernels at the upper one-third of the ear. On the contrary, kernel number and 100-kernel-weight of the middle and basal kernels were reduced as bagging period was prolonged. Based on the kernel number of the control plant, silking sequence study revaled that pollination of upper spikelets commenced at 3 days after silking (DAS) and was completed at 9 DAS. For middle and basal spikelets, pollination was completed at 5 and 3 DAS, respectively. Negative correlation was recorded between kernel number and 100-kernel-weight. Through changing both kernel number and 100-kernel-weight by controlled pollination, it was assumed that competition existed among kernels at different positions of the ear. An effective pollination period of at least 5 days was also suggested for maintaining kernel yield of th is variety.

Key words: Maize, controlled pollination, kernel-filling, yield.

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基因型與環境交感效應變方成分劃分在落花生品系試驗中環境評估之應用[1]

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摘要　本研究利用二十個落花生品系（種）爲材料，於臺中縣霧峰及雲林縣崙背進行春、秋兩期作之田間試驗，估算籽粒產量之基因型變方成分、環境變方、廣義遺傳率、遺傳相關、基因型與環境交感效應之變方成分，並進行基因型與環境交感效應之變方成分劃分，藉以評估目前農試所品系試驗中對於試區與期作選定之適當性。試驗結果顯示：劃分基因型與環境交感效應之變方成分，在所有情形下，基因型與環境交感效應主要由於不同環境間遺傳相關差異所引起（64.85～99.97%），而僅有一小部分乃係由於不同環境間之基因型變方不等所佔有（0.03～35.15%）。本研究結果建議：爲求正確評估品系之籽粒產量潛力，本所同時在臺中縣霧峰與雲林縣崙背進行春、秋兩期作之品系選拔試驗，乃屬必要。

關鍵詞：落花生，基因型與環境交感效應，基因型變方成分，廣義遺傳率，遺傳相關。

基因型與環境間交感效應（genotype×environment interaction, G×E）是每一位育種家必須面對的問題。由於 G×E 之存在，往往降低了作物外表型與基因型的相關性，而使得選拔工作變得異常複雜[1,4]。育種家或可針對育種目標，將此問題作不同的方式處理，例如：選拔產量高、G×E 小、適應性廣的品種；或選拔產量高、G×E 大、適合於某些特殊環境之品種等等。

早在1951年，Sprague and Federer[28] 即利用變方分析中之均方期望値，在逢機模式假設前提下，估算基因型、環境及交感作用等效應，並用以演算試驗之最適年數、地區數及重複次數。其後，Miller *et al.*[21] 更淸楚劃分各種交感效應之變方成分。Schultz[26] 也加以擴充到混合模式的運用。Plaisted and Peterson[23] 更利用品種×地區變方成分以評估品種之可靠性（dependability）。對於最適試驗年數、地區數及重複次數之估算公式的導衍，以及環境是否逢機等之討論，學者意見頗多[4,8,9,12,17,27]。一般相信，當基因型×年度×地區、或基因型×年度、或基因型×地區等交感效應顯著時，品系評估試驗必須考慮在較多不同的環境下執行，方能得到適應性廣的品種。不過，變方成分分析法，除了 Plaisted and Peterson[23] 的方法外，確實很難提供穩定性基因型之鑑別標準。

Falconer[5] 於1952年即提到可將 G×E 變方成分劃分成二部分，一部分是由於在不同環境下之基因型變方不等所引起，另一部分乃是由於在不同環境之間的遺傳相關不大所引起。就此而言，當 G×E 變方成分顯著時，如果主要是前一部分所佔比例較重，則不一定需要在很多環境下進行品系評估試驗；但如果後一部分所佔比例較重，則非在較多環境下進行評估工作不可。故前一部分對育種家的影響較小，但後一部分將影響育種家對試驗地點、試驗年數的抉擇了。Cockerham[3] 更將 Falconer[5] 原有之二個環境運算公式推衍至多環境之應用。G×E 效應亦可經由選拔而加以改變，Moll *et al.*[22] 及 Hoard and Crosbie[10] 在研究中發現：輪迴選種對直接選拔之性狀具有持續改變其基因型與環境交感效應變方成分的效果，但對間接選拔之性狀則無，他們並致力於增進交感效應變方成

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分中基因型變方差異所佔之比例。

多年來，農試所落花生高級品系試驗均在春、秋兩期作同時在臺中霧峰及雲林崙背進行。此四個環境的評估試驗是否適當？本研究擬利用 G×E 變方成分割分方法，作一檢討。

材料與方法

一、試驗材料：

本試驗使用的材料爲二十個落花生品系（種），取自農試所落花生育種計畫中高級品系（F_{10}～F_{12}）試驗之參試品系（種），其代號名稱及背景資料列如表 1。

Table 1. Background of the twenty peanut lines evaluated.

Line	Background
79F—G—2	79S-O × Tainan S. 9
79F—M—3	N. M. Val. A × Tainan S. 9
79S—A—3	Tainan S. 9 × Manipintar
79S—B—5	Tainan S. 9 × Hypogaea
80F—E—5	75S-F-77 × Tainan S. 9
80F—H—3	75S-F-81 × Tainung 4
80F—I—6	80S-F × Tainan S. 9
80F—P—1	80S-K × PI 315608
80F—Q—2	Tainung 4 × PI 315608
80S—H—2	79F-H × Tainan S. 9
80S—J—2	Tainan S. 9 × Makulu red
80S—X—14	Tainan S. 9 × PI 314817
81S—A—5	Tainan S. 9 × EM 12
81S—C—7	EM 9 × NC Acc. 401
81S—IE—1	N. M. Val. C × PI 337409
81S—IK—8	Tainan S. 9 × N. M. Val. A
81S—IK—9	Tainan S. 9 × N. M. Val. A
81S—IL—2	73-F-150 × N. M. Val. A
Tainan S. 9	Selected from cultivar "GIAY" (Binh Long, Vietnam)
Tainung 5	Spanish white × CJ 444

二、試驗方法：

二十個落花生品系（種），於民國76年春、秋兩期作，在臺中霧峰及雲林崙背同時進行試驗。田間採用逢機完全區集設計，重複四次，5 行區，行長 5m，行株距 35×10cm。肥料用量及田間栽培管理同一般落花生栽培法。成熟收穫後，兩處試區均調查籽粒產量。

三、統計分析：

兩期作兩試區之試驗資料，依 McIntosh [19] 提議的方法進行綜合變方分析，變因計分成：期作（crop）、試區（location）、期作×試區、區集／試區×期作、品系（line）、期作×品系、試

區×品系、期作×試區×品系、及機差（pooled error）等九項，其中期作、試區及品系均設定爲逢機型。各變因之顯著性測驗係以其適當之交感效應行之。其次，依期作及試區之不同，分別作獨立分析，估算變域（range）、平均值（mean, $\bar{X}$）、標準機差（standard error, SE）、環境變異係數（environmental coefficient of variation, CV）、基因型變方成分（genotypic variance component, $\hat{\sigma}_g^2$）、環境變方成分(environmental variance component, $\hat{\sigma}_e^2$)及廣義遺傳率（broad sense heritability, $\hat{h}^2$）。$\hat{h}^2=\hat{\sigma}_g^2/(\hat{\sigma}_g^2+\hat{\sigma}_e^2/r)$, r 爲重複次數，$\hat{h}^2$ 之95%信賴限界（confidence interval, CI）是根據 Kanpp *et al.*[14] 提議的方法計算。兩期作兩試區之四個獨立環境，復又兩兩配對，而成六組變積分析 (covariance analysis) 資料，估算遺傳相關（genetic correlation, $\hat{r}_g$), $r_g=\hat{cov}_{ij}/(\hat{\sigma}_i\cdot\hat{\sigma}_j)$, $\hat{cov}_{ij}$ 爲 i 環境及 j 環境間之基因型變積；$\hat{\sigma}_i^2$ 及 $\hat{\sigma}_j^2$ 爲參試品系分別在 i 環境及 j 環境所估得之 $\hat{\sigma}_g^2$。基因型與環境交感效應變方成分（genotype by environment component of variance, $\hat{\sigma}^2_{gxe}$）則又依四、三及二個環境之不同，分別估算之。最後，循Cockerham[3] 的方法，將 $\hat{\sigma}^2_{gxe}$ 劃分成兩個部分，一部分爲不同環境下之基因型變方不等所引起，另一部分乃由於不同環境下之遺傳相關差異所引起。其估算公式列如下：

$$\hat{\sigma}^2_{gxe}=\sum_{i<j}\frac{(\hat{\sigma}_i-\hat{\sigma}_j)^2}{e(e-1)}+\sum_{i<j}\frac{2\hat{\sigma}_i\hat{\sigma}_j(1-\hat{r}_{ij})}{e(e-1)}$$

$\hat{r}_{ij}$ 即爲合併 i 環境及 j 環境所估得之 $\hat{r}_g$, e 爲環境數目。

結果與討論

兩期作兩試區之試驗資料經綜合變方分析，結果列如表 2 。其中期作×試區及期作×試區×品系等效應均爲極顯著，品系效應爲顯著。在春、秋兩期作，霧峰試區之變域均略大於崙背試區（表3）。平均值間比較，不管是霧峰試區或崙背試區，春作均顯著高於秋作。環境變異係數介於11.3~13.5%之間，崙背試區之春、秋作均略高於霧峰試區。

實際育種工作中，育種家對於品系評估試驗之環境選定是非常重要的。環境的適當與否，將影響選種效率以及育種成敗。一般而言，在有利環境下（favorable environment）或最適環境下（optimum environment），由於環境變異（environmental variation）較小，或環境變異受到較

Table 2. Combined analysis of variance for kernel yield (kg/ha) of 20 peanut lines grown at two locations in spring and fall crop of 1987.

Sources of variation	df	Mean squares
Crops	1	41,957,642
Locations	1	142,883
Crops×Locations	1	4,382,155**
Blocks/Locations×Crops	12	147,247
Lines	19	486,070*
Crops×Lines	19	159,199
Locations×Lines	19	151,261
Crops×Locations×Lines	19	141,298**
Pooled error	228	38,147

*, ** : Significantly different from 0 at α = 0.05 and 0.01, respectively.

Table 3. Range, mean ($\bar{X}$), standard error (SE) and environmental coefficient of variation (CV) for kernel yield (kg/ha) among 20 peanut lines.

Estimates	Wu-feng		Lung-bei	
	Spring	Fall	Spring	Fall
Range (kg/ha)	1,298.2—2,638.9	405.2—1,673.2	1,499.5—2,327.8	788.8—1,708.2
$\bar{X}\pm$SE (kg/ha)	2,220.2± 134.8	1,262.0± 71.4	1,943.9± 131.1	1,453.7± 97.4
CV (%)	12.1	11.3	13.5	13.4

有效的控制，基因型得以充分表現，基因型間之差異也較容易被辨識出來。在此種環境下，外表型與基因型亦更爲接近（廣義遺傳率較高），選拔效率理當相對的提高 (2,6,7,11,15,16,18,20,22,24,25)。當然，廣義遺傳率同時受到基因型變方成分與環境變方大小所左右，由其估算公式可知，並非基因型變方成分大者，其廣義遺傳率必大 (11)。本試驗中，所有兩期作兩試區之基因型變方成分及廣義遺傳率均顯著異於0（表4），在四個環境所估得之基因型變方成分，同一試區之春秋作間約略相近；但由於環境變方差異較大，兩試區均爲春作大於秋作（1.8~3.6倍），故廣義遺傳率亦有懸殊(表4)。單就廣義遺傳率觀之，品系評估試驗在臺中霧峰進行似乎比在雲林崙背有利；而秋作評估似更優於春作評估。

爲了進一步瞭解參試品系在不同環境間相互之遺傳相關關係，遂將兩期作兩試區之四個環境兩兩配對，計分成六組。結果遺傳相關値介於0.0024~0.8332之間，其中四組達極顯著，兩組不顯著。遺傳相關高，表示所有參試品系對兩個環境差異表現較爲一致之反應；反之，遺傳相關小，則表示至少部分參試品系對兩個環境差異表現相當不一致之反應（表5）。

在兩個以上的環境評估一批育種材料，尤其當參試基因型多的情況下，環境與基因型交感問題極難避免。一般認爲，當基因型與試區或基因型與期作交感效應顯著時，基因型應在多試區或多期作下進行評估與選拔。在此情形下，當然亦可將基因型或試區依特殊需要加以分割，以減小交感效應的發生，並育成適合某些特殊區域需要的作物品種。本試驗中，基因型與環境交感效應之變方成分，四個環境下所估得之値爲25,236，四組三個環境下所估得之値介於16,835~69,704，六組二個環境下所估得之値介於11,150~42,339之間（表5）；不管是四、三或二個環境之分割，所有基因型與環境交感效應之變方成分均達極顯著。

另一方面，依 Falconer (5) 及 Cockerham (3) 之解釋，基因型與環境交感效應之變方成分可劃分成兩部分，一部分主要爲不同環境下之基因型變方不等所引起，另一部分主要爲不同環境間的遺傳相

Table 4. Estimates of variance component and heritability for kernel yield (kg/ha) of 20 peanut lines

Estimates	Wu-feng		Lung-bei	
	Spring	Fall	Spring	Fall
$\hat{\sigma}_g^2$	66,113**	64,249**	25,724**	28,423**
$\hat{\sigma}_e^2$	72,643	20,368	68,787	37,971
$\hat{h}^2$	78.5(57.3, 90.5)+	92.7(85.4, 96.8)	59.9(20.7, 82.4)	75.0(50.4, 89.0)

** : Significantly different from 0 at α = 0.01.

+ : Confidence intervals at 95% level for h^2 estimates are presented in parenthesis.

Table 5. Estimates of genetic correlations ($\hat{r}_g$) and genotype×environment interaction component ($\hat{\sigma}^2_{gxe}$) for kernel yield (kg/ha) of 20 peanut lines.

Environments	$\hat{r}_g$	$\hat{\sigma}^2_{gxe}$
WS—WF—LS—LF	—	25,236.3**
WS—WF—LS	—	32,438.7**
WS—WF—LF	—	16,835.5**
WS—LS—LF	—	69,709.4**
WF—LS—LF	—	28,434.4**
WS—WF	0.6408**	23,417.5**
WS—LS	0.3483**	31,556.1**
WS—LF	0.8332**	11,150.4**
WF—LS	0.0651	42,339,4**
WF—LF	0.7113**	15,939.2**
LS—LF	0.0024	27,008.9**

W : Wu-feng, L : Lung-bei, S : Spring crop, F : Fall crop.
** : Significantly different from 0 at α = 0.01.

關差異所造成。因此，當基因型與環境交感效應存在時，若認定必須在多環境下進行評估試驗就不見得正確了。因爲，若基因型與環境交感效應主要是來自不同環境間之基因型變方差異，則基因型在不同環境間之排名順序並未受影響，在此種情況下，選擇一或少數有利環境或最適環境進行評估試驗，可能正確選拔到所需基因型，而達到提高育種效率的結果；若在多環境下進行評估反而變成多餘而不經濟。反之，若基因型與環境交感效應主要來自不同環境間的遺傳相關差異所造成，那麼，基因型在環境間的排名順序業已改變，如果育種家爲了育成一個適應於多環境之品種，品系評估試驗就非得在多環境下進行不可。由基因型與環境交感效應變方成分劃分公式，亦可看出遺傳變方成分差異與遺傳相關差異相互間對基因型與環境交感效應變方成分的關係，當遺傳相關值等於1時，交感效應將完全由環境間之遺傳變方成分差異所支配；當二遺傳變方成分沒有差異時，交感效應將完全由遺傳相關差異所左右。而當遺傳相關值不等於1時，遺傳變方成分差異愈大，遺傳變方成分差異貢獻於交感效應之比例愈大（如霧峰春作—崙背秋作及霧峰秋作—崙背秋作等）；反之，遺傳變方成分差異愈小，遺傳變方成分差異貢獻於交感效應之比例則愈小（如霧峰春作—霧峰秋作）。但不管如何，當遺傳變方成分差異存在時，遺傳相關愈小，遺傳相關差異部分所貢獻於交感效應之比例必然愈大（如霧峰秋作—崙背春作及崙背春作—崙背秋作），這將不利於育種家的評估與選拔工作。因此，對育種家而言，當遺傳相關值高且遺傳變方成分差異大時，乃是最有利的。本試驗中，很不幸的，不管是四個環境下、四組三個環境下或六組二個環境下，其交感效應變方成分劃分結果（表 6 ），基因型變方成分差異部分（V）均未達50%，而遺傳相間差異的部分（C）却占了64.85～99.97%。因此，品系評估試驗在現有之四個環境進行，似乎已不可免。

在多年度多試區進行試驗，當進行變方分析時，亦經常面臨模式設定之爭議問題 (9.21.26)。一般多將年度與試區設定爲逢機型，而將參試品系設定爲固定型。在某些試驗中亦有很多學者將品系設定爲逢機型。就統計的觀點而言，將有限的幾個年度、試區及品系假設爲所有可能年度、地區及品種之一逢機樣品，其代表性都値得商榷。育種家往往必須考慮到試驗進行的困難及解釋上的需要，而有不同的看法 (3.4.6.10.11.15.16.21.22.28)。本試驗中，將期作、試區及品系均設定爲逢機型，也有便利運算及解釋之考量，只是，這裏將品系假設爲農試所歷年來所有參與品系試驗之一組逢機材料，而其延伸之參

Table 6. Partitioning of genotype×environment interaction component for kernel yield (kg/ha) into the component due to differences in genotypic variance (V) and due to differences in genetic correlations from one environment to another (C).

Environments	V	C
WS—WF—LS—LF	2,761.6 (10.94)	22,474.7 (89.06)
WS—WF—LS	3,005.2 (9.26)	29,433.5 (90.74)
WS—WF—LF	2,508.9 (14.90)	14,326.6 (85.10)
WS—LS —LF	8,625.2 (12.37)	61,084.2 (87.63)
WF—LS —LF	2,657.1 (9.34)	25,777.3 (90.66)
WS—WF	6.7 (0.03)	23,410.8 (99.97)
WS—LS	4,679.3 (14.83)	26,876.8 (85.17)
WS—LF	3,919.7 (35.15)	7,230.7 (64.85)
WF—LS	4,331.9 (10.23)	38,007.5 (89.77)
WF—LF	3,602.3 (22.60)	12,336.9 (77.40)
LS—LF	33.6 (0.12)	26,975.3 (99.88)

W : Wu-feng, L : Lung-bei, S : Spring crop, F : Fall crop.
Percentage estimates of the portion of $\hat{\sigma}^2_{gxe}$ are presented in parenthesis.

考範圍亦將僅及於農試所之品系試驗部分。本研究原擬利用基因型與環境交感效應之變方成分割分方法，尋出多年來農試所落花生品系試驗沿用之試驗環境間之關係，藉以探討是否能縮減試驗環境以達到節省人力物力及提高育種效率的可能，很顯然的，根據本資料分析結果，農試所落花生品系試驗至少仍需於春、秋兩期作同時在臺中霧峰及雲林崙背進行。至於是否需要在更多之環境下進行品系試驗，則有待進一步研究。

參考文獻

1. Allard, R. W., and A. D. Bradshaw. 1964. Implications and genotype-enviromental interaction in applied plant breeding. Crop Sci. 4 : 503-508.
2. Castleberry, R. M., C. W. Crum, and C. F. Krull. 1984. Genetic yield improvement of U. S. maize cultivars under varying fertility and climatic environments. Crop Sci. 24 : 33-36.
3. Cockerham, C. C. 1963. Estimation of genetic variances. p. 53-94. *In* W. D. Hanson and H. F. Robinson, (eds.), Statistics and Plant Breeding. NSA-NRC. Washington, D. C., Publ. 982.
4. Comstock, R. E., and R. H. Moll. 1963. Genotype-environment interactions. *In* W. D. Hanson and H. F. Robinson (eds.). Statistical Genetics and Plant Breeding. Nat. Academy of Sci.
5. Falconer, D. S. 1952. The problem of environment and selection. Am. Nat. 86 : 293-298.
6. Frey, K. J. 1964. Adaptation reaction of oat strains selected under stress and non-stress environmental conditions. Crop Sci. 4 : 55-58.
7. Gotoh, K., and S. Osani. 1959. Effectiveness of selection for yield under different fertilizer levels in a wheat cross. Jap. J. Breed. 9 : 173-178.
8. Gupton, C. L., P. D. Legg, L. A. Link, and N. F. Ross. 1974. Genotype×environment interactions in barley tobacco variety tests. Crop Sci. 14 : 811-814.
9. Hanson, W. D. 1964. G×E interaction concepts for field experimentation. Biometrics 20 : 540-553.
10. Hoard, K. G., and T. M. Crosbie. 1986. Effects of recurrent selection for cold tolerance on genotype-

environment interactions for cold tolerance and agronomic traits in two maize populations. Crop Sci. 26 : 238-242.

11. Johnson, G. R., and K. J. Frey. 1967. Heritabilities of quantitative attributes of oats (*Avena* sp.) at varying levels of environmental stress. Crop Sci. 7 : 43-46.
12. Jones, G. L., D. F. Matzinger, and W. K. Collins. 1960. A comparison of flue cured tobacco varieties repeated over locations and years with implications on optimum plot allocation. Agron. J. 52 : 195-199.
13. Kempthorne, O. 1969. An introduction to genetic statistics. The Iowa State Univ. Press. Ames, Iowa. U. S. A.
14. Knapp, S. L., W. W. Stroup, and W. M. Ross. 1985. Exact confidence intervals for heritability on a progeny mean basis. Crop Sci. 25 : 192-194.
15. Lambert, R. J. 1978. Breeding corn in a non-limiting environment. p. 24-33. *In* Proc. Annu. Corn and Sorghum Res. Conf., Chicago, IL. 12-14. Dec. Amer. Seed Trade Assoc. Washington, D. C.
16. Lambert, R. J. 1984. Reciprocal recurrent selection of maize in a high-yield environment. Maydica 29 : 419-430.
17. Liang, G. H., E. G. Heyne, and T. L. Walter. 1966. Estimates of variety×environmental interactions in yield tests of three small grains and their significance on the breeding program. Crop Sci. 6 : 135-139.
18. Lu, H. S., and R. J. Lambert. 1988. Response of two maize populations to reciprocal recurrent selection in a high-yield environment. J. Agric. Res. China 37(4) : 366-378.
19. McIntosh, M. S. 1983. Analysis of combined experiments. Agron. J. 75 : 153-155.
20. Medeski, H. J., and D. L. Jeffers. 1973. Yield response of soybean varieties grown at two soil moisture stress levels. Agron. J. 65 : 410-412.
21. Miller, D. A., J. C. Williams, and H. F. Robinson. 1959. Variety-environment interactions and their implications on testing methods. Agron. J. 51 : 132-135.
22. Moll, R. H., C. C. Cockerham, C. W. Stuber, and W. P. Williams. 1978. Selection response, genetic-environmental interaction, and heterosis with recurrent selection for yield in maize. Crop Sci. 18 : 641-645.
23. Plaisted, R. L., and L. C. Peterson. 1959. A technique for evaluating the ability of selection to yield consistently in different locations or seasons. Amer. Potato J. 36 : 381-385.
24. Rosielle, A. A., and J. Hamblin. 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci. 21 : 943-946.
25. Rumbaugh, M. D., K. H. Asay, and D. A. Johnson. 1984. Influence of drought stress on genetic variances of alfalfa and wheatgrass seedlings. Crop Sci. 24 : 297-303.
26. Schultz, E. F. Jr. 1955. Rules of thumb for determining expectations of mean squares in analysis of variance. Biometrics 25 : 427-430.
27. Schutz. W. M., and R. C. Bernard. 1967. Genotype × environment interactions in regional testing of soybean strain. Crop Sci. 7 : 125-130.
28. Sprague, G. F., and W. T. Federer. 1951. A comparison of variance components in corn yield trials. II. error, year×variety, location×variety and variety components. Agron. J. 43 : 535-541.

Partitioning of Genotype by Environment Component of Variance in Peanut Yield Trials[1]

H. S. Lu, W. L. Tsaur, and J. H. Yang[2]

Summary

Twenty peanut lines were grown in replicated yield trials at two locations in spring and fall crops of 1987. Genotype, environment, genotype×environment interaction effects and genetic correlations for kernel yield of peanut were estimated. In order to determine the optimum combination of crops and locations in peanut yield trials, genotype× environment components of variance were partitioned into two parts: one due to difference in genetic correlations from one environment to another and another due to the differences in genotypic variance.

(1) Partitoning of $\hat{\sigma}^2_{gxe}$ indicated: a substantial portion (64.85—99.97%) of the $\hat{\sigma}^2_{gxe}$ was due to differences in genetic correlations, and only a small portion (0.03—35.15%) accounted for by differences in genotypic variance from one environment to another.

(2) Results from this study suggested: TARI peanut yield trial conducted at four environments (Wufeng and Lungbei in spring and fall crops) is necessary if precision of evaluation and selection are concerned.

Key words: Peanut (*Arachis hypogaea* L.), Genotype×environment interaction, Genotypic variance component, Broad sense heritability, Genetic correlation.

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甜瓜品種間同功異構酶變異性之研究[1]

I. 四個甜瓜品種 (PMR 西施，黃金，新玉) 間 peroxidase 及 shikimate dehydrogenase 變異性及其在 F_1 純度鑑定之利用

陳福旗 蕭吉雄 張有明 李弘文[2]

摘要 本試驗用洋香瓜系統 PMR 和西施及東方甜瓜系統黃金香瓜和新玉等四種之自交系及其雜交後代，以電泳方法調查種子及幼苗子葉所含同功異構酶之變異性。在調查的十種酵素中，只有 peroxidase (PRX) 及 shikimate dehydrogenase (SkDH) 具有多型性。PMR 屬於 PRX-2B2B，而西施、黃金香瓜和新玉則屬於 PRX-2A2A；PMR 和西施具有 SkDH-SS 型，而黃金香瓜和新玉則爲 SkDH-FF 型。由 PMR×新玉的 F_2 後裔分析SkDH之分離比，可以推斷此酵素爲由一個基因座的兩個對偶基因 (Skdh-F 及 Skdh-S) 所控制，各表現出單一條帶，PRX-2 亦由一個基因座的兩個對偶基因所控制，但各表現出三個條帶，其 F_1 爲混合型，具有四個條帶。兩系統間的 F_1 可以用此兩種酵素的同功異構酶來鑑定其純度，但系統內品種間則酵素無差異，無法測定比較其純度。

關鍵詞：甜瓜、同功異構酶、F_1純度鑑定。

甜瓜 (*Cucumis melo* L.) 種類極多，每年本省的栽培面積達一萬公頃以上 [1]，爲重要瓜果蔬菜。瓜類具有雜種優勢，雜交一代甜瓜具有生長勢强，整齊度高，豐產，早生，抗病性强及品質佳等優點 [13]，加上種苗公司爲了保有其既得利益，亦積極推廣一代雜交品種；因此在走向專業化企業化經營的農業，具有豐產，品質及整齊度高的雜交一代甜瓜種子的生產，將是未來市場的主流。

瓜類的一代雜交種子純度在商業上具有重要意義，種子純度高，其商品價值亦高。以往判斷蔬菜種子純度的方法就是播種後檢驗一定數量植株樣品中是否有異形株 [6]。目前已有許多報告指出，利用同功異構酶系統可以鑑定某些蔬菜雜交種子的純度，其方法較前者快速而且可信度較高。商業種子中，甘藍 [7] 及番茄 [14] 已經利用同功異構酶來檢查種子純度，頗有成效。

在生產雜交種子時，由於自然異交授粉，親本自花授粉，採收果實時混淆或包裝時種子混雜 [7,14]，都可能是造成種子不純的原因，因此快速種子純度的鑑定，對種苗企業具有相當的價值。

傳統上利用幼苗生長測定種子純度，有時無法分辨何者爲非雜交種子，何者爲雜交種 [14]；另外，如果沒有顯性標識基因控制的性狀，有時苗期亦難檢定其純度，因此發展出應用生化分析鑑定的方法，來快速檢定種子的純度，其中又以同功異構酶分析最爲實用 [7]。

有關甜瓜的同功異構酶的文獻較少， Dane [8], Eaquinas-Alcazar [10] 及 Perl-Treves [12] 等報告利用同功異構酶的多型性 (polymorphism) 來研究甜瓜及同屬其他物種間的演化關係，從而推斷甜瓜的變異中心。Dane [8] 指出，控制 peroxidase (PRX) 的基因有Px1, Px2, Px3 及 Px4，其他酵素如 acid phosphatase (APS), phosphoglucoisomerase (PGI) 均由兩個基因座控制，

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江口[5]報告 esterase 在不同變種間有差異性。目前尚未發現利用同功異構酶來鑑定甜瓜一代雜交種純度的報告。本文主要目的爲探討四個甜瓜品種間同功異構酶的變異性，及其用在甜瓜雜交種子純度鑑定的可行性。

材料和方法

1.植物材料

本試驗所用材料爲 PMR，西施兩種洋香瓜，黃金香瓜和新玉兩種東方脆瓜之自交系，PMR×西施，PMR×黃金和 PMR×新玉等之 F_1，及（PMR×新玉）之 F_2。將上述材料的種子浸種後，於 30—32°C 生長箱黑暗下催芽，第二天去殼後整粒使用。另外發芽的種子播於蛭石，在溫室中生長一至二個星期，取其葉片或子葉供同功異構酶分析用。

2.電泳分析

將催芽的種子，幼苗的子葉或葉片置於約 300ul 緩衝液（含 0.1M Tris-HCl, pH 7.5, 1mM EDTA, 10mM KCl, 2mM $MgCl_2$ 及 14mM 2-Mercaptoethanol），另加少許 PVP-40 粉末磨碎，此萃取液再分成二步驟使用：粗萃取液用0.4× 1 公分的 Whatman #3 濾紙吸收後，用澱粉膠進行電泳分析（表 1），剩下的溶液經 15,000 rpm 離心（Hitachi SCR20BA 離心機，4°C）10分鐘後，上澄液用於同樣澱粉膠或 7.5%聚丙烯醯銨膠體電泳分析，以比較粗萃取液和純化後的溶液內同功異構酶的解析力。

表 1 本試驗採用之澱粉膠電泳緩衝液系統

Table 1. Buffer systems used for starch gel electrophoresis.

系統	膠體	電極槽	電力設定
A	一份 Lithium borate (0.04M LiOH, 0.19M boric acid) pH8.3 九份 Tris-citrate (0.05M Tris, 0.007M citric acid) pH8.3	只用 Lithium borate	300V 或 35mA
A1*	A+10mg $NADP^+$	A+8-10mg $NADP^+$	300V 或 35mA
B	電極緩衝液稀釋20倍	7.7g/l Citric acid, 9.5ml N-(3-aminopropyl) Morpholine, pH6.1	35—40mA
C	0.007M DL-histidine pH7.0	0.135M Tris, 0.043M Citric Ccid, pH7.0	35mA

*Durham et al. 1987.

澱粉膠體電泳方法主要依照已發表的報告[2]，但略做修改。澱粉膠係使用水解的馬鈴薯澱粉（Sigma S-4501），溶於緩衝液系統（表 1），在酒精燈上加熱至沸騰後，脫氣，倒入鑄模，隔天使用。電泳時，將吸有萃取液的濾紙插入三分之一處切開的澱粉膠中，兩端用纖維素海綿當鹽橋，在 2—4°C 之下，通以 35mA 定電流或300伏特定電壓（表 1），並用 bromophenol blue 當作示蹤劑（tracking dye），當示蹤劑距原點 9 —10公分時，停止電泳，將膠體取出，水平切割成四片，最上一片丟棄，其餘三片則分別用生化反應染色法染 aconitase (ACO), peroxidase (PRX), phosphoglucoisomerase (PGI), malate dehydrogenase (MDH), isocitrate dehydrogenase (IDH), phosphoglucomutase (PGM) 和 6-phosphogluconate dehydrogenase (6-PGD).

聚丙烯醯銨膠體電泳依照吳和卓[4]的方法，所用膠體爲7.5%，以每片膠體 30mA 的定電流進行電泳，同樣用 bromophenol blue 做示蹤劑，當其跑到距前端 1 — 2 公分時，停止供電，分別染 shikimate dehydrogenase (SkDH), glutamate dehydrogenase (GDH) 及 glutamate oxal-oacetate transaminase (GOT).

表 2 本試驗所調查的酵素及電泳緩衝液系統

Table 2. Enzymes and buffer systems investigated.

Enzyme	Buffer system
Aconitase (ACO)	A
Isocitrate dehydrogenase (IDH)	A
Glutamate dehydrogenase (GDH)	P
Glutamate oxaloacetate transaminase (GOT)	P
Malate dehydrogenase (MDH)	B
Peroxidase (PRX)	A, C
Phosphoglucomutase (PGM)	A, A1
Phosphogluconate isomerase (PGI)	A, A1
6-Phosphogluconate dehydrogenase (6-PGD)	B
Shikimate dehydrogenase (SkDH)	P, B

P : 7.5% polyacrylamide gel.

3.染色

酵素染色均依照Vallejos[15]的方法，PRX及PGI已詳述於陳及李之報告[1]，其餘酵素敍述如下：

MDH : 0.1M Tris, pH 7.5, 100ml; 1M DL-malate, pH7.5, 3ml; NAD^+ 30mg; MTT 20mg; PMS 4mg. 在黑暗 30—35°C 染色。

GDH : 0.1M Tris, pH8.0, 100ml; Na-glutamate 400mg; NAD^+ 30mg; NBT 25mg. 在黑暗 30—35°C 染色，通常需要隔夜才能顯現清楚條帶。

GOT : 1. 0.1M Tris, pH 8.5, 100ml; α-ketoglutarate 100mg; Aspartic acid 200mg，上述混合攪拌15分鐘。

2. Pyridoxal 5-phosphate 10mg; Fast blue BB salt 150mg (溶於 1ml 丙酮)。以上兩種溶液在染色前混合，在黑暗 30—35°C 染色 2—4 小時。

SkDH : 0.1M Tris, pH8.0, 100ml; Shikimic acid 50mg; NADP 10mg; MTT 15mg; PMS 2mg. 在 30—35°C 黑暗下染色10—45分鐘。

PGM : 0.05M Tris, pH 8.0, 100ml; α-D-glucose 1-P, 75mg; α-D-glucose 1, 6-dP 2mg; 0.1M MgCl2 5ml; Glucose 6-P dehydrogenase 40 units; NADP 5 mg; MTT 10mg; PMS 2mg. 在 30—35°C 黑暗下染色。

6-PGD 0.1M Tris, pH 7.5, 100ml; $MgCl_2$ 98mg; 6-P gluconic acid 20mg; $NADP^+$ 15 mg; MTT 20mg; PMS 4mg.

IDH: 0.1M Tris, pH8.0, 100ml; Isocitric acid Na 100mg; 1M $MgCl_2$ 5mg; NADP 10mg; MTT 15mg; PMS 2mg.

結　果

在所分析的10種同功異構酶中，只有 PGI 解析力較差，以 A 或 A1 緩衝液系統電泳的結果相似，都只能分辨兩群約三個條帶。ACO 在澱粉膠及 A 緩衝液系統中無法偵測到酵素活性。PGM 呈現兩條清楚而分開的條帶，在供試品種間並無差異。PGD 在各品種間均為移動性相同的兩條酶型，單株之間酵素活性有強有弱，有時只看到一條。以聚丙烯醯銨膠體電泳分析 GDH ，供試各品種間均

呈現一個條帶，其移動性相同。GOT 則均爲三個條帶，且可分爲兩群，品種間沒有差異。IDH 同樣也是具有兩個條帶，沒有差異。MDH 在膠片的正極上均呈現三個條帶，而負極的酵素活性較低，不易判斷是二或三個條帶，但品種之間也沒有差異。另外，種子活力較低時，各 MDH 的同功異構酶活性較低，且會分解產生移動性不同的條帶，催芽後胚根沒有生長的種子則只有極弱的活性。

SkDH 及 PRX 在供試品種間具有差異，該兩種酵素的分析情形敍述如下：

1. Shikimate dehydrogenase (SkDH)

甜瓜幼苗子葉或催芽種子內含的 SkDH 主要有兩型，一個是 Rf=0.47 的條帶，一個是 Rf=0.50 的條帶（圖1），Rf 0.47 型的前端尚有三條次要的條帶（Rf 分別爲 0.49，0.51，0.53），後端（Rf<0.47）另有一條次要條帶，這些條帶在有些個體較强，有些個體較弱。Rf 0.5 型的也有一條次要條帶（Rf=0.51），也是在有些個體强，有些個體弱。Rf 0.47 型的品種有 PMR 及西施，而 Rf 0.5 型的品種有黃金及新玉(圖1)。Rf 0.47×Rf 0.5 的後代呈混合型，其 F_1 均具有 Rf 0.47 及 Rf 0.5 條帶（圖1），偶而也有次要條帶出現於 F_1，但不影響結果之分析，以 PMR，新玉及其 F_1, F_2 再分析一次時，可見到 PMR 的次要條帶（圖2箭頭所指）很明顯，但在 PMR×新玉的 F_1 個體就很淡，而在其 F_2 代樣品中可見兩個主要條帶會分離，由於不同批電泳結果，其 Rf 值稍有變化，因此將圖1中 Rf 0.5 條帶暫時命名爲 SkDH-F，而 Rf 0.47 條帶命名爲 SkDH-S，分

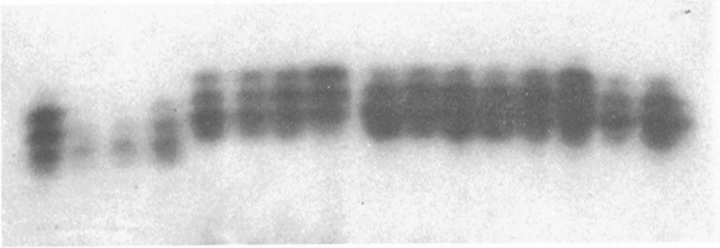

圖1. 甜瓜的 SkDH 酶型圖。主要的條帶爲 Rf 0.47 及 Rf 0.50. 前者命名爲 SkDH-S，後者命名爲 SkDH-F. 381=PMR, 382=西施，383=黃金，384=新玉，385=PMR ×西施，386=PMR×黃金，387=PMR×新玉，390=387F_2.

Fig. 1. Zymogram of melon SkDH isozymes. Major bands have Rf value of 0.47 and 0.50. The former is named as SkDH-S and the latter SkDH-F, respectively. 381=PMR, 382=Hsi-Shih, 383=Hwang-Jin, 384=Shin-Yuh, 385=PMR×Hsi-Shih, 386=PMR×Hwang-Jin, 387=PMR×Shin-Yuh, 390=387F_2.

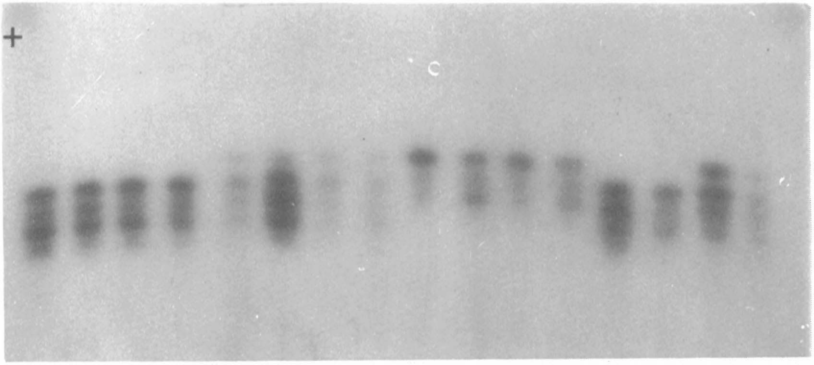

圖2. PMR，新玉兩個甜瓜品種及其 F_1, F_2 幼苗子葉中的 SkDH 同功異構酶。從圖右開始 1—4 行=PMR，5—8行=PRM×新玉，9—12行=新玉，13—16行=（PMR×新玉）F_2. 在本圖中，PMR 的 SkDH-SS 多了一條明顯的次要條帶（箭頭所指）。

Fig. 2. SkDH isozymes in seedling cotyledons of PMR, Hsin-Yuh, F_1 and F_2. Note an minor band (arrow) appeared in SkDH-SS of PMR. For right to left, lanes 1—4=PMR, 5—8=PMR×Hsin-Yuh, 9—12=Hsin-Yuh, 13—16=(PMR×Hsin-Yuh) F_2.

析52株 PMR×新玉的 F_2 結果爲（表現型）：11FF, 27FS, 14SS，經卡方測驗分析，得 $x^2=0.42$，其値在 P=0.05 時小於3.84，顯示符合孟德爾一對基因的1：2：1之比，因此推斷供試材料的 SkDH 由一個基因座的兩個共顯性對偶基因（*Skdh-F* 及 *Skdh-S*）所控制。

2. Peroxidase (PRX)

催芽但尚未照光的種子所含的 PRX 活性較弱，且只有靠近膠體原點的部份才有條帶出現，這顯示 PRX 的表現受到發育階段的控制。若以幼苗的綠色子葉分析 PRX 時，近正極的位置可見到兩種不同移動性的三個條帶（圖3），PMR 品系的 PRX 爲移動性較慢的三條，而西施，黃金及新玉品系的 PRX 爲較快的三條，且兩群間有二條重疊（圖3），因此 PMR ×新玉呈現四條 PRX（圖4），而 F_2 則分離成三型，依據 Dane (1983) 的命名，供試材料的 PRX 表現型可命名爲 PRX-2A2A, 及 PRX-2B2B，其 F_1 爲 PRX-2A2B，而 F_2 則分離成 PRX-2A2A, PRX-2A2B 及 PRX-2B2B，因此暫時將其基因定爲 *Prx-2A* 及 *Prx-2B*，由分離情形可以推斷是由一個基因座兩個對偶基因所控制，PMR 品系的基因型屬於 *Prx-2B2B*，而其他三個品系的基因型則爲 *Prx-2A2A*.

若澱粉膠體以不同的緩衝液來分析，所得的結果也類似，但其解析力有差異，以 C 緩衝液（表1）分析 PRX 時，某些條帶的表現就比較不淸楚（圖4），但其條帶分佈則和 A 系統的類似。

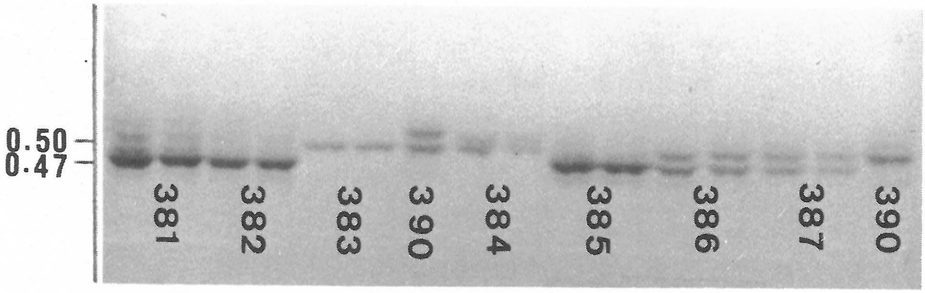

圖3. 四個甜瓜品種的 PRX-2 酶型圖。（由左至右）1—4行=PMR，5—8行=西施，9—12行=黃金，13—16行=新玉。

Fig. 3. Zymogram of PRX-2 in four melon varieties. From left to right, lanes 1—4=PMR, 5—8=Hsi-Shih, 9—12=Hwang-Jin, 13—18=Shin-Yuh.

圖4. 甜瓜幼苗子葉的 PRX-2 在10%澱粉膠 A 緩衝液系統上的酶型圖。（由左至右）1—4行=PMR，5—8行=PMR ×新玉，9—12行=新玉，13—16行=（PMR ×新玉）之 F_2 代。圖中只顯示正極的條帶，其餘尚有分佈在原點和負極的條帶則未顯示出來。PMR 屬於 PRX-2B2B，新玉屬於 PRX-2A2A，其 F_1 則爲 PRX-2A2B.

Fig. 4. Banding pattern of PRX-2 allozymes in cotyledons of young melon seedlings resolved in 10% starch gel with buffer A. Other isozyme bands near the origin and the cathode are not shown.

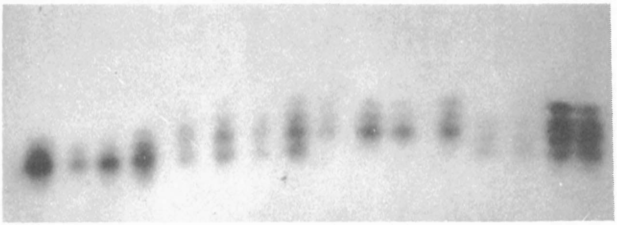

圖5. 甜瓜幼苗子葉的 PRX-2 同功酶以緩衝液 C 系統解析的酶型圖。樣品排列順序和圖4相同。圖中可看出 PRX-2B 條帶（由左起1—4行）不够清楚。

Fig. 5. Banding pattern of PRX-2 allozymes in cotyledons of young melon seedlings resolved in 10% starch gel with buffer C Sample arrangement is the same as figure 4.

綜合 PRX 及 SkDH 的資料，可依其基因型將 PMR，西施，黃金及新玉等四個甜瓜品系歸納如表3所示。

表3. 四個甜瓜品種的 *Prx-2* 及 *Skdh* 基因型

Table 3. Genotypes of *Prx-2* and *Skdh* isozyme in four melon varieties.

品　　種	*Prx-2*	*Skdh*
PRM	B B	S S
西　施	A A	S S
黃　金	A A	F F
新　玉	A A	F F

討　　論

由試驗結果顯示，PMR 品系的酶型爲 PRX-2B2B, SkDH-SS；西施品系的酶型爲 PRX-2A2A, SkDH-SS；黃金香瓜的酶型爲 PRX-2A2A, SkDH-FF；而新玉品系則爲 PRX-2A2A, SkDH-FF（表3）。PMR 和西施均爲果面具有網紋，果肉橙黃色，質軟，具芳香的洋香瓜系統（*Cucumis melo* L. var. *reticulatus*），而黃金和新玉香瓜爲果皮光滑，果肉淺綠或色白，質脆的東方甜瓜系統（*C. melo* L. var. *makuwa*）[2]，初步顯示兩種系統在 PRX 及 SkDH 酵素的表現，很明顯的部份具有系統內共同性及系統間差異性（洋香瓜系統具有PRX-2B2B 或 PRX-2A2A, SkDH-SS；東方甜瓜系統爲（PRX-2A2A, SkDH-FF），依 Mallick 及 Masui [11] 的報告，*C. melo* 共有40個變種，在型態上可分爲數群，其變異性極大，在生化特性上，控制同功異構酶的基因除 *Prx-2* 及 *Skdh* 之外，值得進一步探討不同系統間或系統內之其他酶型變異性。江口 [5] 於1968年報告用 esterase 酶型可以區分 var. *reticulatus*, 和 var. *makuwa* 及其他幾個變種，洋香瓜系統（var. *reticulatus*）具有M1, M2, M7, M8, M9, M10 條帶，而東方甜瓜系統（var. *makuwa*）具有M1, M2, M3, M8, M9, M10 條帶，因此兩系統之間的區分，到目前爲止共有三種酵素可以利用。最近 PGD 利用改良過的電泳條件，可以看出具有兩型，詳細情形將另外報告。若能將所有商業品種或其他變種調查其 PRX 及 SkDH 的表現型，在品種鑑定上將可配合形態性狀及核酸的 RFLP（限制片段長度多型性）標示因子，而可將品種分門別類，這對育種者或種苗公司有重要意義。

系統間雜交的 F_1 可以用酶型來鑑定種子純度，PMR×新玉的 F_1 以 PRX 鑑定時，均呈 PRX-2A2B 型（具四個條帶），因此如果種子中混有親本型（PRX-2A2A 或 PRX-2B2B），將很容易用此酵素篩檢出來，而可計算種子的純度百分率。Tanksley 及 Jones [14] 報告利用 ADH (alcohol

dehydrogenase) 可以鑑定番茄一代雜交種的純度，他們指出，利用澱粉膠體電泳分析種子純度的優點為：分析速度快且便宜，利用種子分析，不需很大的溫室空間。在本試驗中，我們利用種子或幼苗來分析 PRX 及 SkDH ，所需空間也很小，在一代雜交種子純度鑑定上，可加以利用，以幼苗供試還有一個好處，即單株經過分析之，可使其繼續生長，而供其後之雜交，遺傳或其他特性調查。

除了純度鑑定之外，酵素基因和形態性狀或其他園藝性狀是否連鎖，（例如本文之 PRX 及 SkDH 與果皮網紋或光滑之關係），可以分析其 F_1, F_2 及回交代之分離情形，而找出連鎖關係，如番茄的 *Aps-1* 與抗線蟲性狀 (*Mi*) , *Prx-2* 與雄不稔性 (*Ms*) 連鎖，南瓜的 *Aldo-2* 與抗西瓜嵌紋病毒之連鎖等[16] ，這些均為在育種上極有價值的標示因子，而於早期能够快速篩檢出需要的性狀，甜瓜如能找到類似之連鎖關係，將可提高育種效率及縮短所需時間。

參考文獻

1. 陳福旗，李弘文。1988。簡易澱粉膠體電泳裝置及其在同功異構酶上的應用。中華農業研究37（1）：24—31。
2. 邱阿昌。1972。甜瓜 (*Cucumis melo* L.) 遺傳及育種之進展。科學農業20 (3.4) ：243—250。
3. 臺灣省政府農林廳。1987。臺灣農業年報。
4. 吳明哲，卓俊銘。1986。柑桔葉片同功異構酶之研究。Ⅰ.本省重要柑桔葉片之電泳分析與葉齡對分析結果之影響。中華農業研究35（4）：484—494。
5. 江口弘美。1968。 *Cucumis melo* 果實における糖蓄積，ならびにエステラーゼ組成からみた品種分化，メロン育種の問題點。園藝學會小集演講要旨，46—56（錄自：農業技術大系野菜編4 ：1—32，農山漁村文化學會）。
6. Arus, P. 1983. Genetic purity of commercial seed lots. In: Isozymes in Plant Genetics and Breeding, Part A, p. 415-423, (Tanksley, S. D. & T. J. Orton, eds), Elsvier, Amsterdam.
7. Arus, P., S. D. Tanksley, T. J. Orton & R. A. Jones. 1982. Electrophoretic variation as a tool for determining seed purity and for breeding hybrid varieties of *Brassica oleracea*. Euphytica 31 : 417-428.
8. Dane, F. 1983. Cucurbits. In: Isozymes in Plant Genetics and Breeding, Part B, p. 369-390, (Tanksley, S. D. & T. J. Orton, eds), Elsevier, Amsterdam.
9. Durham, R. E., G. A. Moore & W. B. Sherman. 1987. Isozyme banding patterns and their usefulness as genetic markers in peach. J. Amer. Soc. Hort. Sci. 112(6) : 1013-1018.
10. Esquinas-Alcazar, J. T. 1977. Allozyme variation and relationships in the genus *Cucumis*. PhD Dissertation. Universitt of California, Davis, California, 170pp.
11. Mallick, M. F. R. & M. Masui. 1986. Origin, distribution and taxonomy of melons. Scientia Hort. 28 : 251-261.
12. Perl-Treves, R., D. Zamir, N. Navot & E. Galun. 1985. Phylogeny of *Cucumis* based on isozyme variability and its comparison with plastom phylogeny. Theor. Appl. Genot. 71 : 430-436.
13. Peterson, O. H. 1983. Heterosis in vegetable crops. In: Heterosis, pp. 138-188, (Frankel, R., ed), Springer-Verlag, Berlin.
14. Tanksley, S. D. & R. A. Jones. 1981. Application of alcohol dehydrogenase allozymes in testing the genetic purity of F_1 hybrids of tomato. HortScience 16(2) : 179-181.
15. Vallejos, C. E. 1983. Enzyme activity staining. In: Isozymes in Plant Genetics and Breeding, Part A, pp. 469-516, (Tanksley, S. D. & T. J. Orton, eds), Elsecier, Amsterdam.
16. Weeden, N. F. 1989. Applications of isozymes in plant breeding, Plant Breed. Rev. 6 : 11-54.

Isozyme Variation in *Cucumis melo* L.

I. Peroxidase and Shikimate dehydrogenase variation in four melon varieties and its application for F_1 hybrids identification[1].

F. C. Chen, C. H. Hsiao, Y. M. Chang and H. W. Li[2]

Summary

Four melon Inbred lines, belonging to var, *reticulatus* and *maukwa* and their progenies were used for studying isozyme variation in either seeds or young cotyledons. Among ten enzymes investigated, two were found to be polymorphic. They are peroxidase (PRX) and shikimate dehydrogenase (SkDH). For PRX, variety PMR has the phenotype of 2B2B, while Hsi-Shih, Hwang-Jin, and Shin-Yuh belong to 2A2A type. For SkDH, varieties PMR and Hsi-Shih have the phenotype of SS, while Hwang-Jin and Shin-Yuh belong to FF type. Samples from selfing progeny of a PMR×Shin-Yuh cross were analysed for segregation in SkDH locus. The result showed that it was controlled by a single locus of two alleles, each encoded a single band of different mobility. Similarly, PRX-2 may also found to be controlled by a single locus of two alleles, each expressed different three-banded pattern. The two genes were named as *Skdh* and *Prx-2*, respectively. Hybrid between genotype *Prx-2A2A* and *2B2B* revealed four banded patterns, which indicated the codominance nature of the enzymes. Seed purity in hybrid could be monitored between two parents having different isozyme patterns.

Key Words : melon, isozyme, F_1 hybrids identification

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Nutritional and Environmental Conditions for the Growth of *Coriolus versicolor*, a Wood Decaying and Medical Fungus[1]

Ying-Ming Liao[2]

Abstract *Coriolus versicolor* is a wood decaying fungus, it also has been used as a medicine in chinese tradition to cure many chronic diseases. However, it is also a harmful fungus on the logs in shiitake cultivation. Heavily infection of the logs by *C. versicolor* easily wiped out the production of shiitake. Three isolates of *C. versicolor* were used to explore the nutritional requirements and environmental conditions for the mycelial growth and fruiting body formation of *C. versicolor*. Results of the PDA plate culture indicated that all three isolates grew very well between 28 and 32°C and 12 hours of alternating lights was better than continuous light or darkness. In stationary liquid culture, optimal pH value and C/N ratio were 6.0 and 80. Glucose and mannose were superior to the other carbon sources. Ammonium chloride was best among the nitrogen sources. Urea and sodium nitrite hampered the mycelial growth of *C. versicolor*. Medium amount in the culture container also affected its mycelial growth. In the 300ml flasks, best growth was found with 120ml of medium or 2.5/1 (v/v). Among the amino acids used in the mycelial growth tests, DL-asparatic acid was found best and DL-3 : 4-dihydroxy-phenyl-alanine was harmful. In sawdust cultures, best growth was recorded at the moisture content of 54%. Although the cultural filtrate of *C. versicolor* inhibited the mycelial growth of *C. versicolor* itself, agar medium containing 1000 or 2000ppm of the cultural filtrate of *C. versicolor* favored the mycelial growth of shiitake (*Lentinus edodes*). Formation of fruiting bodies of *C. versicolor* was observed 4 months after inoculation in the sawdust medium consisting of rice bran, wheat meal and calcium carbonate as it is used in shiitake cultivation.

Key words : Environmental Condition, *Coriolus versicolor*, Medical fungus.

Introduction

The wood decaying fungus *Coriolus versicolor* (Fr.) Quel, known as "Yuen-Zhi" (Japanese name "Kawaratake") were found in the decaying wood of apple, malpe and peach trees (1,10,14). It also had been used in the isolation of anti-tumor substances (7,8,9

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,15). Logs used in the cultivation of shiitake were commonly infected by *C. versicolor* and *Stemonitis splendens.* Complete loss of shiitake may occur in the case of heavy infection[5,6]. This may due to the degradation of lignin by the fungus[3,12], thus the nutrients for *L. edodes* is limited. Provious studies indicated that it is a tetrapolor fungus in its mating type[11,14]. Two factors (A, B) were found in the control of its sexual cycle. It has been used as a medicine to cure many chronic diseases in chinese history and tradition and had been grown in the submerged cultures[2,4,13]. Information of this fungus in Taiwan is very limited. In this study , three isolates of *C. versicolor* were isolated from the logs in shiitake cultivation and used in the liquid culture and sawdust experiments. The main purpose was attemped to explore the nutritional requirements and environmental condition for the mycelial growth and fruiting body formation of *C. versicolor* which may be used in the development of control strategies in shiitake production or to develop a simulated medium and/or conditions for the growth or production of *C. versicolor* for medical uses.

Material and method

Isolation of the fungus : Isolates L-7501 and L-7502 were isolated from the logs of shiitake production in Puli in July and Sept. 1986, respectively. Isolate L-7601 was isolated from logs in Tuku in July 1987. They were grown on PDA at 28°C for mycelial growth and then maintained at 16°C for use.

Survey of *C. versicolor*-infection on the shiitake logs : Various kinds of logs two years after inoculation of *L. edodes* were surveyed. Infection or mycelial growth and fruiting body formation on each species of logs were observed by naked eyes and individually recorded. The percentage of infection and the kind of infected logs were summarized in Table 1.

Effect of temperature on the mycelial growth of *C. versicolor* : Agar discs (0.5cm) of the three isolates of *C. versicolor* were seperately transferred on the center of DPA plates. The plates were incubated at 16, 20, 24, 28, 32 and 36°C for 7 days without light and colony diameters for each isolate were recorded. Experiments were conducted three times with four replicates. Data were summarized in Table 2.

Effect of light on the mycelial growth of *C. versicolor* : Because 28°C was best in the previous test. Therefore 28°C was used in this experiments. PDA plates the same as decribed in temperature tests were incubated in the incubators with 12 hrs of alternating light or continuous light at 28°C, the plates wrapped with black cloth served as continuous dark. Colony diameters were recorded after 7 days. Results were shown in Table 3.

Nutrient requirement in submerged culture : One liter of distilled water containing glucose 30g, $(NH_4)_2HPO_4$ 5g, KH_2PO_4 1g, $MgSO_4$ 0.5g and yeast extract 0.1g, pH 6.0 was used as a basal medium. One each of the 22 carbon sources as listed in Table 4 was seperately added, 5% (w/v), into the basal medium for the comparison of their differences.

Experiments were conducted in 300ml flasks filled with 100ml of testing medium and inoculated with an agar disc (0.5cm) of *C. versicolor*. Under stationary condition, after they were incubated 28°C for 21 days, the mycelia were collected and dried at 60°C for 24hrs before weighting. Twelve nitrogen sources as listed in Table 5 at the concentration of 0.04% (w/v) each, 24 amino acid sources at the concentration of 0.04% (w/v) as listed in Table 6 were also conducted in the same procedures as carbon sources for the evaluation of their effect on the mycelial growth of *C. versicolor*.

For PH value studies, the Mcllavine buffer solution [2] was used in the adjustment of the initial PH value of the basal medium to 3, 4, 5, 6, 7, 8, 9 and 10. PH value were recorded again after sterilization. Agar disc (0.5cm) of different isolates of *C. versicolor* were inoculated. After they were incubated at 28°C for 21 days, the mycelial dry weight also were recorded as previously.

The effect of medium amount on the mycelial growth of *C. versicolor* was also conducted in the basal medium in 300ml flasks containing various amount of medium as listed in Table 8. Mycelial dry weight also was recorded after 21 days.

For C/N ratio studies, calcium nitrate and maltose were used to replace sodium nitrate and sucrose in the Czapek's solution medium and served as nitrogen and carbon sources, respectively. Various amount of C/N ratio as listed in Table 9 were tested and mycelial dry weight were recorded.

Effect of cultural filtrate of *C. versicolor* on the mycelial growth of *C. versicolor* itslef and *L. edodes*: Isolates of ***C. versicolor*** were incubated in the basal medium at 28°C for 21 days as previously described. The cultural filtrates, then, were collected and incorporated with PDA at the concentrations of 50, 100, 500, 1000 and 2000ppm. An inoculum agar disc (0.5 cm) of *C. versicolor* isolate L-7501 or *L. edodes* was inoculated onto the center of the plates. For *L. edodes* the inoculated plates were incubated at 24°C and *C. versicolor* L-7501 at 28°C. The colony diameter were recorded after 14 days.

Effect of water content of sawdust medium on the mycelial growth of *C. versicolor*: Calcium carbonate was used to adjust the PH value of sawdust medium (sawdust 400g, rice bran 60g, and wheat meal 40g) to 6.0. The medium was adjusted to various water contents as listed in Table 12. They were then evenly filled into the glass tubes (22/3cm, length/diameter) as uniformly as purpose. After sterilization at 121°C, 15 lb/in^2, for 30 minutes, the tubes were inoculated at the both ends with various isolates of *C. versicolor*. The growth rates were recorded after 14 days at 28°C.

Cultivation trial of *C. versicolor*: Because *C. versicolor* and *L. edodes* are commonly grown on the same logs, the same sawdust medium (water content 55%) as in the previous test was used. This medium is also commonly used in the shiitake cultivation. The medium was filled into the PP-plastic bags and/or glass bottle. They were then sterilized at the conditions as listed in Table 13. After the inoculation of *C. versicolor* (isolate L-7502), the growing condition or management was the same as growing shiitake. Days for fruiting and dry weight of fruiting bodies for each treatment were recorded.

Results

Infection of *C. versicolor* on the logs of shiitake cultivation

As shown in Table 1, infection or contamination of *C. versicolor* was common on the various kind of logs in shiitake cultivation. The highest percentage, i. e., 18% and 13% of infection were observed on the shiitake log of *Liquidambar formosana* at Puli and Tuku, respectively.

Table 1. Infection of *C. versicolor* on the logs of shiitake two years after inoculation of *L. edodes*

Scientific name of log	Infection percentage (%) of logs by *C. versicolor* at	
	Puli	Tuku
Liquidambar formosana	18*	16
Castanopsis hystrix	10	9
Quercus variabilis	8	8
Cyclobalanopsis glauca	6	7
Engelhardtia roxburghiana	5	5
Elaeocarpus sylvestris	3	4
Alnus formosana	2	2
Acacia confusa	2	1

* : Data were mean of 200 logs of each kind of tree.

Effect of temperature on the growth of *C. versicolor*

As shown in Table 2, mycelial growth was observed between 16°C and 32°C. No growth was observed at 36°C. The optimal temperatures were between 28 and 32°C.

Table 2. Colony diameter (cm) of *C. versicolor* isolates grown on PDA plates at various temperatures for 7 days

Temp. (°C)	Isolate of *C. versicolor*		
	L-7501	L-7502	L-7601
16	3.4*	3.6	3.3
20	7.2	7.4	7.0
24	7.4	7.6	7.2
28	8.0	8.0	7.9
32	8.0	8.0	8.0
36	0**	0	0

*. Data were based on the mean of four plates of PDA medium.
** : O: no visible growth was observed.

Effect of light on the mycelial growth of *C. versicolor*

As shown in Table 3, light is necessary in the formation of fruiting body primodia. For the mycelial growth 12-hrs of alternating light require was superior to the others.

Table 3. Colony diameter (cm) of *C. versicolor* isolates grown on PDA plates at various light conditions at 28°C for 7 days

Treatment	Colony diam. (cm) of *C. versicolor* isolate			Mycelial density
	L—7501	L—7502	L—7601	
continuous light	7.7*	7.6	7.8	primodium formed
12 hrs alternating light	8.0	8.0	8.0	compact
continuous darkness	7.6	7.5	7.6	loose

* : Data were based on the mean of four PDA plates in each treatment.

Table 4. Effect of carbon sources on the mycelial growth of *C. versicolor*

Carbon source*	Mycelial dry weight (mg) of *C. versicolor* isolate		
	L-7501	L-7502	L-7601
Arabinose	0 h	0*** i	0 i****
Cellobiose	288** c	296 c	294 c
Cellulose	104 f	109 f	112 f
Dextrin	110 ef	114 ef	108 f
Fructose	516 a	514 a	508 a
Galactose	212 c	236 c	225 c
Glucose	631 a	628 a	634 a
Glycerol	0 h	0 i	0 i
Inositol	0 h	0 i	0 i
Inulin	134 e	138 e	142 e
Lactose	174 d	178 d	182 d
Maltose	508 a	502 a	511 a
Mannitol	68 g	72 g	66 g
Mannose	624 a	628 a	634 a
Raffinose	172 d	170 d	168 d
Rhamnose	124 e	128 e	116 f
Ribose	0 h	0 i	0 i
Sorbitol	196 d	189 d	202 c
Starch	316 bc	324 b	332 b
Sucrose	96 f	89 f	86 g
Trehalose	56 g	55 h	48 h
Xylose	386 b	389 b	375 b
Control	0 h	0 i	0 i

*. Concentrtion of each carbon source was 5% (w/v) in the basal medium.

**. Mycelial dry weight (mg) of *C. versicolor* isolates after they were incubated at 28°C for 21 days in 300ml flasks containing 100ml of testing medium with 4 replicates.

***. No mycelial growth was observed.

****. Means with the same letter across carbon sources are not significantly different at 5% level by Duncan's Multiple Range Test.

Nutrient requirements in submerged culture

Carbon source. All three isolates of *C. versicolor* could grown in many carbon sources. Maximum mycelial growth was observed in glucose and mannose. No growth was observed in arabinose, glycerol, inositol, ribose and control (basal medium without adding carbon source) (Table 4).

Nitrogen source. Of the 12 nitrogen sources tested, maximum mycelial growth was observed in ammonium chloride, no mycelial growth was observed in urea and sodium nitrite. Good growth was also observed on calcium nitrate and other nitrogen sources. (Table 5)

Table 5. Effect of nitrogen sources on the mycelial growth of *C. versicolor*

Nitrogen source*	Mycelial dry weight (mg) of *C. versicolor* isolate		
	L-7501	L-7502	L-7601
Ammonium acetate	450** a	489 a****	446 b
Ammonium chloride	576 a	614 a	570 a
Ammonium citrate	467 b	478 ab	453 b
Ammonium nitrate	435 b	461 b	428 b
Ammonium phosphate, monobasic	507 a	502 a	483 a
Ammonium sulphate	489 ab	500 a	482 a
Calcium nitrate	566 a	580 a	562 a
Casamino acid	526 a	531 a	539 a
Potassium nitrate	501 a	486 a	477 ab
Sodium nitrate	485 ab	481 ab	470 ab
Sodium nitrite	0***c	0 c	0 c
Urea	0 c	0 c	0 c
Control	475 ab	483 a	469 ab

*. Concentration of each nitrogen source was 0.04% (w/v) in the basal medium.

**. Mycelial dry weight (mg) of *C. versicolor* isolates after they were incubated at 28°C for 21 days in 300ml flasks containinng 100ml of testing medium with 4 replicates.

***. No mycelial growth was oberved.

****. Means with the same letter across nitrogen sources are not significantly different at 5% level by Duncan's Multiple Range Test.

Amino acids. Among the 24 amino acids tested, mycelial growth of C. versicolor was found in the media containing DL-asparatic acid and L-tyrosine, others were found deteriorating to its growth, and no growth observed in the medium containing DL-3:4-dihydroxy-phenyl-alanine (Table 6).

Table 6. Effect of amino acids on the mycelial growth of *C. versicolor*

Amino acid*	Mycelial dry weight (mg) of *C. versicolor* isolate		
	L-7501	L-7502	L-7602
DL-α-alanine	398** c	406 c	411 c****
DL-2-amino-n-butyric acid	569 a	554 a	548 a
L-arginine monohydrochloride	543 a	540 a	542 a
DL-asparatic acid	625 a	614 a	632 a
L-cystine	535 a	532 a	528 a
L-cystine hydrochloride	576 a	558 a	554 a
DL-3 : 4-dihydroxy-phenyl-alanine	0*** e	0 e	0 e
L-glutamic acid	395 c	502 c	416 c
Glycine	537 a	544 a	532 a
L-histidine monohydrochloride	282 d	297 d	278 d
L-hydroxy-proline	580 a	594 a	572 a
DL-iso-leucine	454 b	488 b	476 b
L-leucine	495 b	506 b	516 b
L-lycine monohydrochloride	433 b c	445 b	452 b
DL-methionine	394	398 c	402 c
DL-ornithine monohydrochloride	427 b c	425 b c	438 b c
DL-β-phenyl-alanine	414 c	423 b c	426 b c
L-proline	552 a	546 a	537 a
DL-serine	525 a b	514 a	526 a
DL-nor-leucine	507 b	511 b	518 b
DL-threonine	556 a	552 a	541 a
DL-trytophan	572 a	558 a	563 a
L-tyrosine	604 a	612 a	608 a
DL-valine	582 a	574 a	556 a
Control	602 a	611 a	604 a

*. Concentration of each amino acid was 0.04% (w/v) in the basal medium.

**. Mycelial dry weight (mg) of *C. versicolor* isolates after they were inclubated at 28°C for 21 days in 300ml flasks containing 100ml of testing medium with 4 replicates.

***. No mycelial growth was observed.

****. Means with the same letter across amino acids are not significantly different at 5 % by Duncan's Multiple Range Test.

PH value. The PH values of the medium were always decreased after sterilization. Although good growth was observed in the PH value from 2.8 to 9.7 after sterilization, maximum growth was found roughly between PH 5 and 6 (Table 7).

Table 7. Effect of pH values on the mycelial growth of *C. versicolor*

Initial pH	Final pH after sterilization	Mycelial dry weight (mg) of *C. versicolor* isolate		
		L-7501	L-7502	L-7601
3.0	2.8	458* c **	481 d	498 c
4.0	3.7	638 b	662 b	642 a
5.0	4.7	732 a	744 a	648 a
6.0	5.7	748 a	772 a	660 a
7.0	6.7	652 b	678 b	654 a
8.0	7.7	636 b	651 b c	618 b
9.0	8.8	627 b	624 c	604 b
10.0	9.7	614 b	603 c	598 b

*. Mycelial dry weight (mg) of *C. versicolor* isolates after they were incubated at 28°C for 21 days in 300ml flasks containing 100 ml of testing medium with 4 replicates.

**. Means with the same letter across initial pH are not significantly different at 5% level by Duncan's Multiple Range Test.

Table 8. Effect of medium amount on the mycelial growth of *C. versicolor*

Amount of medium in a 300ml flask	Mycelial dry weight (mg) of *C. versicolor* isolate		
	L-7501	L-7502	L-7601
20 ml	164* f **	202 e	173 f
40	284 e	278 e	189 e
60	513 c	519 c	515 c
80	528 c	538 c	533 c
100	698 b	708 b	678 b
120	918 a	903 a	907 a
140	785 b	776 b	780 b
160	714 b	706 b	723 b
180	504 c	503 d	494 c
200	416 d	426 c	429 d

*. Mycelial dry weight (mg) of *C. versicolor* isolates after they were incubated at 28°C for 21 days in 300ml flasks with 4 replicates.

**. Means with the same letter across amount of media are not significantly different at 5% level by Duncan's Multiple Rang Test.

Amount of medium. The best mycelial growth of *C. versicolor* was found in 300ml flasks filled with 120ml of medium. More or less than 120ml, the amount of mycelial growth was reduced (Table 8).

C/N ratio. Maximum mycelial growth was observed in the medium with C/N ratio at 80, mycelial growth decreased when the C/N ratio was higher or lower than 80 (Table 9).

Table 9. Effect of C/N ratio of medium on the mycelial growth of *C. versicolor*

C/N ratio*	Mycelial dry weight (mg) of *C. versicolor* isolate		
	L-7501	L-7502	L-7601
10	41** f	82 f	59 f ***
20	151 e	106 f	126 e
30	178 d	138 e	164 d
40	238 c	224 d	199 d
50	270 c	262 c	245 c
60	296 b c	285 c	281 c
70	346 b	379 b	358 b
80	517 a	583 a	532 a
90	316 b	373 b	392 b
100	214 d	246 c d	166 d

*. Maltose and calcium nitrate were used as carbon and nitrogen source, respectively, to replace sucrose and sodium nitrate in the Czapek's solution medium.

**. Mycelial dry weight (mg) of isolates of *C. versicolor* grown at 28°C for 21 days in 300ml flasks containing 120ml of different C/N ratio medium, and data were based on the mean of four flasks.

***. Means with the same letter across C/N ratios are not significantly different at 5% level by Duncan's Multiple Range Test.

Table 10. Effect of cultural filtrates of isolates of *C. versicolor* on the mycelial growth of *C. versicolor* isolate L-7501

Cultural filtrate concentration (ppm)	Colony diam. (cm) of *C. versicolor* L-7501 isolate grown in the cultural filtrate of *C. versicolor* isolate		
	L-7501	L-7502	L-7601
50	7.9* a	7.8 a	7.8 a**
100	7.8 a	7.7 a	7.7 a
500	7.5 a	7.4 a	7.5 a
1,000	7.4 a	7.3 a	7.3 a
2,000	5.9 b	6.0 b	6.0 b
Control	8.0 a	8.0 a	8.0 a

*. Colony diameter (cm) of *C. versicolor* isolate L-7501 were based on the mean of four plates at 28°C for 14 days on PDA medium containing various amount of cultrate of *C. versicolor* which was grown in the basal medium for 21 days at 28°C.

**. Means with the same letter across concentrations are not significantly different at 5% level by Duncan's Multiple Range Test.

Effect of cultural filtrate of *C. versicolor* on the mycelial growth of *C. versicolor* itself and *L. edodes*

When the cultural filtrate of *C. versicolor* was incorporated with the medium to grow *C. versicolor*, the growth was inhibited even the concentration was as only 50ppm, and the inhibition increased with the increase of cultural filtrate concentration (Table 10). However, the cultural filtrate of *C. versicolor* increased the growth of *L. edodes* (Table 11, Fig. 1).

Table 11. Effect of cultural filtrates of isolate of *C. versicolor* on the mycelial growth of *L. edodes*

Cultural filtrate concentration (ppm)	Colony diam. (cm) of *L. edodes* grown in the cultural filtrate of *C. versicolor* isolate of		
	L-7501	L-7502	L-7601
50	5.6* c	5.7 c	5.7 c**
100	5.9 b	6.0 b	5.9 b
500	6.0 b	6.0 b	6.0 b
1000	6.6 a	6.5 a	6.5 a
2000	6.9 a	6.8 a	6.8 a
Control	5.5 c	5.4 c	5.4 c

* : Colony diameter (cm) of *L. edodes* were based on the mean of four plates at 24°C for 14 days on PDA medium containing various amount of cultural filtrate of *C. versicolor* which was grown in the basal medium for 21 days at 28°C.

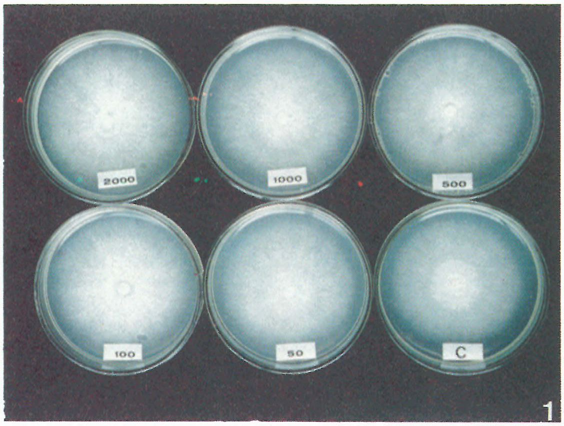
**. Means with the same letter across concentrations are not significantly different at 5% level by Duncan's Multiple Range Test.

Table 12. Effect of water content of sawdus medium on the mycelial growth of *C. versicolor*

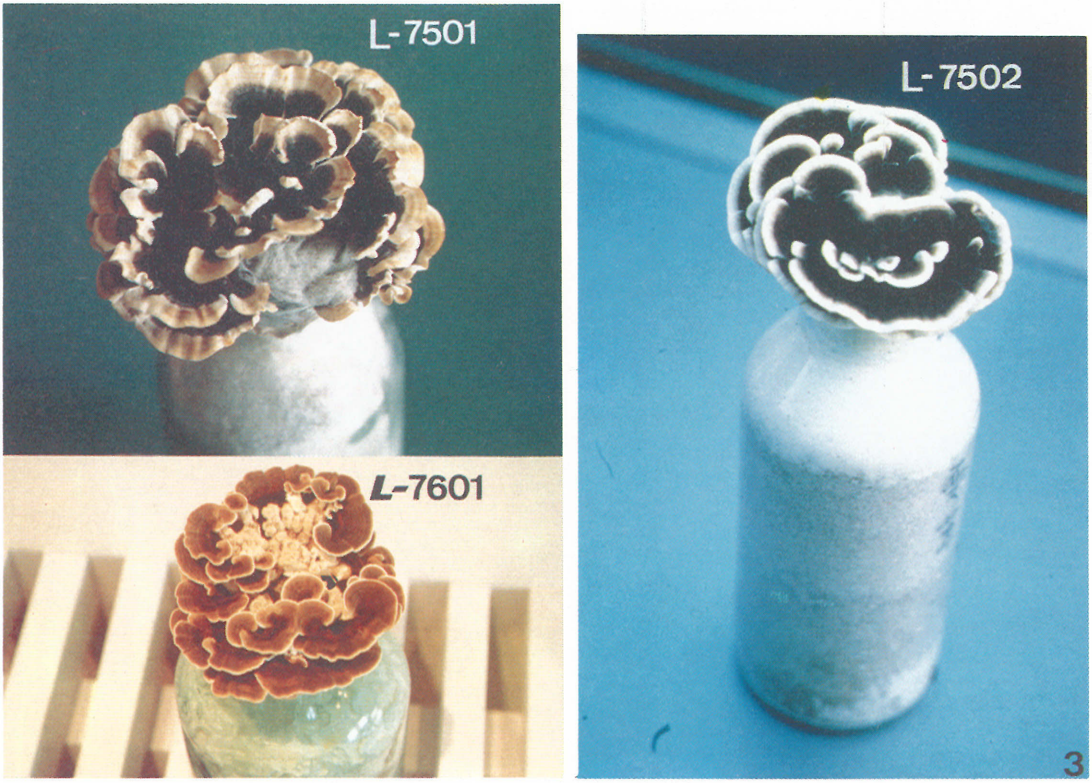
Water content (%) of sawdust medium	Mycelium growth rate (cm/14 days at 28°C) of *C. versicolor* isolate		
	L-7501	L-7502	L-7601
52	18.2* a	18.0 a	17.8 a**
54	19.0 a	19.0 a	19.0 a
59	17.6 a	17.7 a	17.5 a
60	17.4 a	17.4 a	17.5 a
61	17.4 a	17.4 a	17.4 a
62	17.2 a	17.4 a	17.2 a
64	16.4 a b	16.6 a b	16.5 a b
65	15.2 b	15.4 b	15.0 b
66	14.0 b	14.2 b	14.0 b
68	14.0 b	14.1 b	13.8 b
70	11.3 c	10.8 c	11.6 c

*. Data were based on the mean of two observations of mycelial length on both sides of the tubes, and four tubes were conducted for each treatment.

**. Means with the same letter across water contents are not significantly different at 5% level by Duncan's Multiple Range Test.


2000
1000
500
100
50
C
1

Coriolus versicolor
54%
59%
60%
61%
62%
64%
65%
66%
68%
70%
2


L-7501
L-7601
L-7502
3

Effect of water content of sawdust medium on the mycelial growth of *C. versicolor*

Optimal mycelial growth was observed in the sawdust medium containing 54% of moisture (Table 12, Fig. 2). It seems that the moisture between 50 and 60% were all suitable. If the moisture higher than 70%, the mycelial growth was greatly inhibited.

Cultivation trial of *C. versicolor*

Fruiting body formation was observed in all three type of vessels, 120 to 140 days after inoculation depending upon the vessel type. Highest yield of fruiting body was observed in 1000ml-glass bottles, followed by 2000ml-plastic bags and 500ml- glass bottles (Table 13).

Table 13. Cultivation trials of isolate L-7502 in different vessels

Item	Vessel and capacity		
	plastic bag (2000 ml)	glass bottle (500 ml)	glass bottle (1000 ml)
condition of sterilization	98°C for 4 hrs.	121°C, 15 lb/in^2 for 60 min.	121°C, 15 lb/in^2 for 90 min.
wt. of medium	1,000g	400g	800g
dry wt. (g) of fruiting bodies*	21.3(b)**	18.4(c)	32.8(a)
days for fruiting	140	120	130

*. The dry weights were based on the mean of 20 bags or bottles.

**. Means with the same letter across dry wt. of fruiting bodies are not significantly different at 5% level by Duncan's Multiple Range Test.

Discussion

Among the shiitake logs tested, maple tree (*Liquidambar formosana*) was the one that is most easily infected by *C. versicolor* (Table 1). Although *Stemonitis splendens* is also commonly observed in the shiitake logs, it is more easily found on the logs of *Engelhardtia roxburghiana* [6]. Results indicated that the basal medium used in this study is suitable for the growth of *C. versicolor*. Similar results were also obtained by Darbyshire et al [1]. Fruiting body primodia of *C. versicolor* were observed in the cultures exposed to the continuous light (Table 3). It seems that light is necessary in the process of fruiting body formation.

Factors such as temperature, PH value, amount of medium in a 300ml flask, C/N ratio of medium, carbon source, nitrogen source, and amino acid may greatly affect the mycelial growth of *C. versicolor*. Results of this study indicated that the optimal temperature was 28°C (Table 2), the best carbon sources were glucose and mannose (Table 4), the best nitrogen sources were ammonium chloride and calcium nitrate (Table 5), the best amino acid was DL-asparatic acid (Table 6) which is very similar

to that for *L. edodes*[13], the optimal PH values for mycelial growth was between 5 and 6 (Table 7).

The appropriate amount of medium in 300ml flask was 120ml (Table 8). All the results decribed above were very similar to that of *L. edodes* reported by the previous authors[5,13]. The best C/N ratio of medium for the growth of *C. versicolor* was about 80 (Table 9). However, *Lepiota naucina*, *Agaricus bisporus*, and *Volvariella volvacea* were reported at 25, 30, or 60[5,13]. It means that different fungi need different C/N ratio for their growth.

Cultural filtrate of *C. versicolor* did not inhibited the growth of *L. edodes.* The incorporated cultural filtrates may provide extra nutrients, therefore, the colony diameter of *L. edodes* increased with concentration of the cultural filtrate incorporated (Table 11). It seems that the growth of shiitake inhibited by *C. versicolor* on the logs was due to the vigorous growth of *C. versicolor* which resulted in the comsumption of nutrients or the competition of growing space. Water content of sawdust did affect the growth of *C. versicolor.* Although 54% was the best, moisture between 50 and 60, in general, were all suitable (Table 12), and it was very similar to the conditions of other wood decaying fungi. *C. versicolor* produced fruiting bodies in all three type of vessels tested (Fig. 3). However, days from inoculation to fruiting body formation varied. The smaller the vessels, the lesser the days needed for fruiting (Table 13). It may due to the nutrient in the smaller vessels became a limiting factor, which induced fruiting body formation was sooner than the larger vessel, *C. versicolor* and other wood decaying fungi such as *Ganoderma lucidum* and *G. applanatum* are commonly used as medicine to control many human diseases. However, information of cultivation was limited. This study may provide as a basis to explor their mysterious in nature. Obviously, further research is needed.

Literature Cited

1. Darbyshire, B.; G. C. Wade and K. C. Marshall, 1969, In the vitro studies of the role of nitrogen and sugars on the susceptibility of apple wood to decay by *Trametes.* Phytopathology 59 : 98-102.
2. Kim, H. K. et al, 1988, Studies on the mycelial growth condition of *Agrocybe aegrita.* (In Korean). Res, Rept. RDA (E. Fm, S, F, P. U., & M.) 30(3) : 141-150.
3. Kirk, T. K., 1973, Polysaccharide integrity as related to the degradation of lignin in wood by white-rot fungi. Phytopathollogy 63 : 1504-1507.
4. Liao, Y. M., 1983, Effect of light, composition of medium, pH, and temperature on the mycelial growth of *Lepiota naucina.* Jour. Agric. Res. China 32(2) : 139-145.
5. Liao, Y. M, 1985, Efficacy of fungicides on the control of *Trichoderma* spp. in sawdust cultivation of shiitake. Jour. Agric. Res . China 34(3) : 329-340.
6. Liao, Y. M., 1986, Occurrence and life cycle of *Stemonitis splendens* on the logs of shiitake. Jour. Agric. Res. China (35) : 511-520.
7. Mizuno, T.; S. Ohtahara and J. Li, 1988, Mineral composition and germanium content of several medicinal mushrooms. Bull. Fac. Agr. Shizuoka Univ. 38 : 37-46.
8. Mizuno, T. et al, 1988, Immunostimulative-antitumor effects of β-D-glucans and chitin substances

isolated from some medicinal mushrooms. Bull. Fac. Agr. Shizuoka Univ. 38 : 29-35.

9. Mizuno, T., 1989, Development and utilization of bioactive substances from mushroom. Nippon Nogeikagaku Kaishi 63(4) : 861-865.
10. Ohtani, T. and J. Kishimoto, 1977, Variation of tannins by crude enzyme of *Polyporus versicolor*. (In Japanese). Bull. Fac. Agric. Tottori Univ. 29 : 29-34.
11. Raynor, A. D. M. and N. K. Todd, 1978, Polymorphism in *Coriolus versicolor* and its relation to inter fertility and intra specific antagonism. Tran. Br. mycol. Soc. 71(1) : 99-106.
12. Rosenberg, S. L., 1980, Patterns of diffusibility of lignin and carbohydrate-degrading systems in wood-rotting fungi. Mycologia 72 : 798-812.
13. Song, C. H.; K. Y. Cho and N. G. Nair, 1987, A synthetic medium for the production of submerged cultures of *Lentinus edodes*. Mycologia 79(6) : 866-876.
14. Williams, E. N. D. and N. K. Todd, 1984, Characterization of the spore rain of *Coriolus versicolor* and its ecological significance. Trans. Br. mycol. Soc. 82(2) : 323-326.
15. Yanagi, S. and M. Hamada, 1976, On the antitumor effects of fungal extracts. Trans . mycol. Soc. Japan (In Japanese) 17 : 506-514.

一種木材腐朽菌及藥用真菌—雲芝，其生長之營養及環境條件之探討[1]

廖英明[2]

摘　要

雲芝 (*Coriolus versicolor*) 是一種香菇段木栽培時常見的害菌，但自古以來它也是用作防治慢性病的眞菌。一旦受其感染，則該段木幾無收成可言。三個雲芝菌株在 PDA plate 上培養結果顯示，最適溫度爲 28—32°C ，且在12小時光照，12小時黑暗時，菌絲生長最好。故在探討營養要求方面之液體培養試驗時均在 28°C 下，靜置培養21天，培養結果顯示 Glucose 及 Mannose 爲最佳碳源，Ammonium chloride 爲最佳氮源，但 Urea 及 Sodium nitrite 反不利 *C. versicolor* 菌絲之生長。在所有供試之氨基酸中，DL-asparatic acid 有利雲芝菌絲生長，DL-3 : 4-dihydroxy-phenyl-alanine 則不利。而在 pH 值爲6.0及C/N ratio 爲80時菌絲生長最好。培養液容量也會影響菌絲生長，在 300ml 的三角瓶中，若含 120ml 的培養液，則可得到最多之菌絲乾量。而木屑培養時最適當之含水量爲 54%。本菌其培養液會影響其自身之生長，但是若以 1,000ppm 或 2,000ppm 之量混合在固體培養基中，反有利香菇菌絲之生長。本試驗之三個菌株都可在栽培香菇用之木屑培養基中產生子實體，培養期約四個月。木屑培養基中含有米糠；麥粉及碳酸鈣等添加物。

關鍵詞：環境條件、雲芝、藥用眞菌。

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2.本所植物病理系助理研究員。臺灣省　臺中縣　霧峰鄉。

中華農業研究 (Jour. Agric. Res. China) 39(3) : 204~207 (1990)

The Latent Period of Peanut Witches' Broom Agent in the Vector *Orosius orientalis*[1] (Research Note)

I. L. Yang and S. Y. Wu[2]

Abstract The minimum periods of the acquisition and inoculation feedling for the insect transmission of peanut witches' broom disease are six hours and one hour, respectively. The minimum incubation period of the disease agent in the vector *Orosius orientalis* is 11 days.

Key words : Peanut witches' broom, vector, *Orosius orientalis* Matsumura, latent period.

In 1956, Bergman [1] first reported the peanut witches' broom (PnWB) disease in Java. Since then, the little leaf or witches' broom on leguminous plants were reported in Australia [2], Ryukyu [4] and Taiwan [3]. These diseases were confirmed to be transmitted by *Orosius orientalis* (Evans) and *O. orientalis* Matsumura. Because of the prevalence of the PnWB disease in Taiwan, studies on the latent period of PnWB agent in the insect vector *Orosius orientalis* Matsumura were made.

The leafhopper vector *O. orientalis* collected from peanut fields at Penghu and Miaoli areas were propagated on healthy food plants of peanut in insectaries, where the temperature was maintained at 24—28°C. The nymphs of second and third stages of *O. orientalis* were used as insect vectors for testing the aquisition, incubation and inoculation periods. The acquisition feeding period on transmission was tested by varying the feedling time of the insects on the diseased plants. The acquisition feeding period tested for PnWB were 2, 3, 6, 8, 24 and 48 hours. Forinoculation feeding period, the insects were grouply exposed to the diseased plants for 24 days, then the exposed insects were transferred to test plants for 1/3, 1/2, 1, 3, 6, 8 and 24 hours for inoculation feedling. For incubation period of PnWB agent in the vector, the leafhoppers were fed on the PnWB-diseased plants for 7 days for acquisition feeding, then the exposed insects were each transferred to test plants for 2, 3, 4, 5, 6, 8, 10, 12 and 14 days for inoculation feeding. Two week-old peanut seedling were used as test plants, and the inoculated plants were grown in a greenhouse for three months for symptom observations.

For acquisition feeding period of *O. orientalis* in relation to infection of PnWB, longer acquisition feeding tended to cause higher infection of the disease. The minimum acquisition feeding period was determined to be 6 hours. None of the insect which had

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Table 1. Acquisition feeding period of *Orosius orientalis* in relation to infection of peanut witches' broom disease

Acquisition feeding period (hr)	Incubation feeding period (day)	Inoculation feeding period (day)	Total transmission[a]	
			No.	%
2 (70 — 80)[b]	14 — 28	4	0 / 16	0
3 (70 — 80)	14 — 28	4	0 / 16	0
6 (70 — 80)	14 — 28	4	1 / 16	6.25
8 (70 — 80)	14 — 28	4	1 / 16	6.25
24 (70 — 80)	14 — 28	4	5 / 16	31.25
48 (70 — 80)	14 — 28	4	7 / 16	43.25

a. Numerator/denominator=Infected plants/inoculated plants.
b. Numbers in the parenthesis indicate number of insects tested in colony.

Table 2. Inoculation feeding period of *Orosius orientalis* in relation to infection of peanut witches' broom disease

Acquisition feeding period (day)	Inoculation feeding period (hr)	Total transmission[a]	
		No.	%
21 (50 — 60)[b]	1 / 3	0 / 18	0
21 (50 — 60)	1 / 2	0 / 18	0
21 (50 — 60)	1	1 / 18	5.56
21 (50 — 60)	3	3 / 21	14.29
21 (50 — 60)	6	3 / 21	14.29
21 (50 — 60)	8	4 / 21	19.05
21 (50 — 60)	24	6 / 18	33.33

a. Numerator/denominator=Infected plants/inoculated plants.
b. Numbers in the parenthesis indicate number of insects tested in colony.

Table 3. Transmission of peanut withches' broom disease by insect vector *Orosius orientalis* at different incubation periods

Acquisition feeding period (day)	Inoculation feeding period (day)	Total transmission[a]	
		No.	%
7 (47)[b]	2 (33)	0 / 8	0
7 (41)	3 (32)	0 / 8	0
7 (53)	4 (42)	2 / 10	20
7 (42)	5 (34)	1 / 8	12.5
7 (56)	6 (45)	2 / 8	25
7 (51)	8 (38)	2 / 10	20
7 (46)	10 (32)	3 / 8	37.5
7 (42)	12 (34)	3 / 8	37.5
7 (52)	14 (38)	4 / 8	50

a. Numerator/denominator=Infected plants/inoculated plants.
b. Numbers in the parenthesis indicate number of insects tested in colony.

been exposed for 3 hours could transmit the disease (Table 1). For inoculation feeding period, longer inoculation feeding tended to cause higher infection of the disease. As shown in Table 2, 1/2 hour inoculation feeding was not enough to induce disease infection, and the minimum inoculation feeding period was one hour. For incubation period, the minimum incubation period of PnWB agent in the leafthopper vector was 11 days (Table 3).

The authors are indebted to Drs. J. Ishihara, M. J. Chen, H. J. Su, and Mr. K. S. Lin for their support and help in this study.

Literature cited

1. Bergman, B. H. H. 1956. Mosaic I and withes' broom disease of the Groundnut (*Arachis hypogaea* L.) in West Java and their vector, the jassid *Orosius argentatus* (Evans). Tijdschr. Pljidkt, 62 : 291-304. (cited from Rev. Appl. Mycol. 36, 448, 1957)
2. Bowyer, J. W. 1974. Tomato big bud, legume little leaf, and lucerne witches' broom: Three diseases associated with different mycoplasma-like organisms in Australia. Aust. J. Agric. Res. 25 : 449-457.
3. Lo, T. C., and Y. H. Han. 1969. Studies on witches' broom of soybean. Bot. Bull. of Acad. Sinica 10 : 10-22.
4. Shinkai, A. 1964. Studies on insect transmission of sweet potato witches' broom disease in the Ryukyu Islands. Spec. Res. Rep. Agric. Sec. Econ. Dep. Ryukyu Islands 1-44.

落花生簇葉病病原在媒介昆蟲南斑葉蟬之潛伏期[1]

楊一郎　吳淑雅[2]

落花生簇葉病病原之經由南斑葉蟬（*Orosius orientalis* Matsumura）媒介傳染必需之最短獲毒吸食時間爲 6 小時，最短接種吸食時間爲 1 小時，媒介蟲體內之最短潛伏時間爲11天。

關鍵詞：落花生簇葉病、媒介昆蟲、南斑葉蟬、潛伏期。

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Insecticide Resistance Study in *Plutella xylostella* L.

X. The IGR-resistance and the possible management strategy[1]

Cheng, E. Y., C. H. Kao and C. S. Chiu[2]

Abstract : The benzoylphenyl urea-type insect growth regulators (IGRs) have caused the newest type of resistance in diamondback moth (DBM, *Plutella xylostella*). The possible mechanism, the declining rate, the genetics and the possible management strategy of this resistance have been investigated. The results indicated that DBM can develop IGR-resistance up to thousand folds in less than one and half years or equal to 30 generations in field, and this resistance is attributed to the metabolic degradation by a new mixed function oxidase (mfo) in DBM induced from the intensive IGR sprays. The resistance can only be maintained by continuous IGR selection, or it will decline when the selection pressure was lift. The decline of IGR-resistance can be accelerated by crossing the susceptible strain with the resistant population, and by such a simple manipulation, greater reduction in resistance was accomplished than the addition of synergist, piperonyl butoxide. Genetically, the IGR-resistance is not sex-linked and is highly recessive, and has not been confirmed as the monofactorial control. When the susceptible gene for IGR was re-introduced into the resistant population, this genetical dominance can self-propagate as the generations proceed. In a few generations, the whole population will restore the high sensitivity to IGRs, which was similar to the susceptible strain. By establishing sanctuary in the field to harbor a portion of DBM population free from the IGR selection, the dominant susceptible gene or genes will be preserved in the field DBM to delay or prevent the development of IGR-resistance. This strategy can be utilized in intensively cultured vegetable areas where small areas are kept free from IGRS to serve as the sanctuary for IGR-susceptible DBM.

Key words : *Plutella xylostella*, insecticide resistance, teflubenzuron, chlorfluazuron

Introduction

Ever since the benzoylphenyl urea (BPU)-type insect growth regulators (IGRs) were introduced to Taiwan in 1987 for the diamondback moth (DBM, *Plutella xylostella*) control, the possibility of developing IGR-resistance has become of great concern because sporadical alerts on the IGR-resistance in DBM had been reported previously in

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Thailand (Cheng, 1988; Vattanatangum, 1988). The DBM had been shown to possess a natural mfo metabolic activity toward diflubenzuron and triflumuron (Cheng et al., 1988), and a mild teflubenzuron resistance was induced in DBM by the laboratory selection (Perng et al., 1989). The mfo degradation serves as the resistance mechanism for IGRs in the houseflies and DBM (Pimprikar and Georghiou, 1979; Lin et al., 1989). Within two years of marketing of IGRs in Taiwan, the IGR-resistance appeared in DBM and reached more than thousand folds. During the same span, TARI had been continually monitoring the field DBMs for the IGR-resistance. Several characters on the IGR-resistance in DBM were studied which included the possible mechanism, the natural declining rate of resistance, and the IGR-resistance in genetics. Hopefully, a better understanding of IGR-resistance in DBM and the possible management strategy can be elucidated

Materials and methods :

Insect materials

The susceptible IL(TC)-strain (Cheng et al., 1988) was used and the generations being used during this study were 58 to 78, a span of more than 20 generations. No changes in the IGRs sensitivity were observed.

IGR-resistant DBMs were collected either from different locations or from the same site at different times, and were used to (1) identify the IGR-resistance and (2) select the high IGR-resistant DBM for particular study. The resistant strains included:

Lu-chu (LC) strain (collected several times during 1988).

Juang-wei (JW) strain (Sept. 1989 from I-lan county).

Hsi-hu (HH) strain (Oct. 1989 from Changhua county).

San-chung (SC) strain [Oct. 1989 from Taipei county and the collecting site was close to the BC-strain appeared in previous DBM resistance study (Cheng et al., 1988)].

Insecticides

All insecticides used were commercially formulated and they were :

Teflubenzuron, 5% EC

Teflubenzuron, 13.5% FP

Chlorfluazuron, 5% EC

Fenvalerate, 10% EC

For the test, high concentrations of insecticide stocks were first made, and a series dilutions according to experimental design were followed. Usually, 5 to 7 dosages between LC_{10} and LC_{90} were chosen.

Synergist

Piperonyl butoxide (pb) was obtained from Tokyo Kasai, and was first formulated into 50% emulsion stock, and then mixed with target insecticide in 5 to 1 ratio (active ingredient) for testing.

Testing procedures

Third instar larvae of DBM were subjected to various insecticide susceptibility tests by using the Potter Spray Tower for spraying treatment. For every test, one side of a

cabbage leaflet ($5\times5cm^2$) was sprayed with 1ml of insecticide solution first, and then 20 DBM larvae were loaded on the other side of the leaf and sprayed again by another 1ml insecticide solution. A minimum total of 60 larvae in three replicas were treated per dosage. The post-treatment holding temperature and humidity were controlled at $25\pm1°C$ and $85\pm10\%$, respectively. The mortality was counted every 24 hours until pupation. The final mortality, usually at 120 hours after treatment, was recorded for probit analysis.

Testing items

1. The development of IGR-resistance in the field DBM population : Ever since IGRs were introduced for DBM control, the DBM in Lu-chu area has been periodically sampled for IGR-sensitivity test to examine the resistance development. Later, IGR-sensitivity test was also conducted on DBMs sampled from other locations in the insecticide resistance monitoring program.

2. The synergistic effect of pb: IGR-resistant DBMs from 5 locations around Taiwan were used to test whether the synergistic effect of pb is universal and to probe if there is any resistance mechanism other than the oxidative metabolic degradation.

3. The decline of IGR-resistance after release from the selection pressure : To understand the possible changes of IGR-resistance after the stopage of IGR use by farmers. The sensitivities of LC-strain to three commercial IGR products were determined on every three generations for 17 generations.

4. Genetic tests by crossing the IGR-resistant and the susceptible strains for the following purposes :

   a. Whether the IGR-resistance is sex-linked
   b. Whether the genetic nature of IGR-resistance is dominant or recessive
   c. Whether the IGR-resistance is controlled by a single gene.

5. Laboratory testing on the reduction of IGR-resistance through the genetic manipulation.

Results

1. Development of IGR-resistance in the field DBM populations

In Taiwan, the original sensitivities (LC_{50}) of field DBMs to chlorfluazuron and teflubenzuron had never exceeded 10ppm in early 1987, however, the DBM resistance to IGRs had developed within a short period in the LC-areas (Fig. 1). The susceptibility to chlorfluazuron had changed from 3.8ppm in March to 924ppm in December, 1988, an increase of 243 folds in resistance ratio. By the end of 1989, DBMs collected from four other locations showed varied chlorfluazuron resistance as the LC_{50} ranged from 61.0 to 1685.7ppm, while the sensitivities to teflubenzuron in five DBM populations ranged from 100.5 to 72,628.6ppm (Table 1). The above results indicated clearly that the field DBM populations in Taiwan had developed IGR-resistance.

2. The synergistic effect of pb

The IGR-resistance observed in Taiwan DBM populations was greatly affected by the action of piperonyl butoxide. The synergistic ratio (S. R.) were 7.9 to 10.4 for

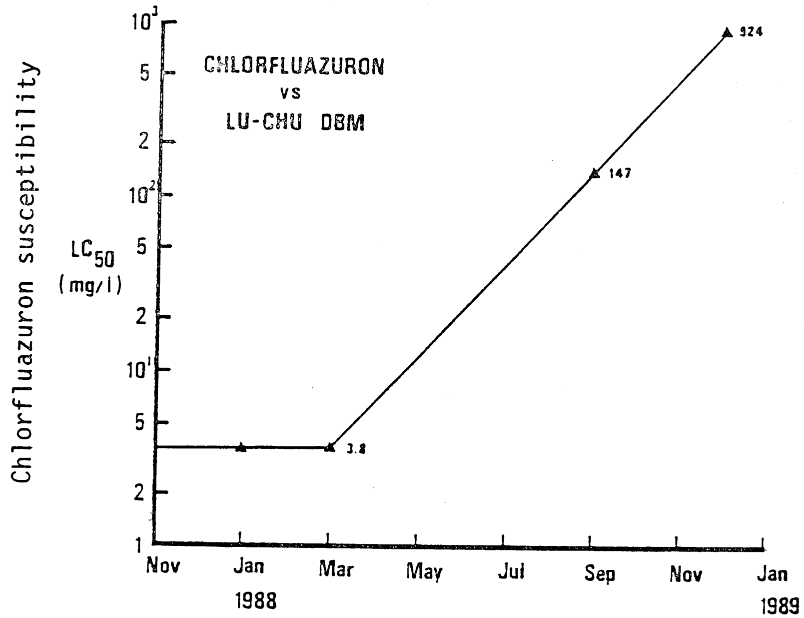

Figure 1. The chlorfluazuron susceptibility changes in Lu-chu DBM from Jan. to Dec, 1988.

Table 1. The synergistic effect of piperonyl butoxide to IGRs and synthetic pyrethroids against field resistant *Plutella xylostella**

Insecticide treatments	LC_{50} in ppm				
	$HH(F_2)$	$KW(F_3)$	$SC(F_4)$	$IL(F_3)$	$LC(F_2)$
IGRs					
Teflubenzuron alone	209.4	100.5	4,613.3	4,534,3	72,628.6
Teflubenzuron +5pb	26.4	—	444.8	475.2	—
Synergistic ratio	(7.9)	—	(10.4)	(9.5)	—
Chlorfluazuron alone	162.0	61.0	701.3	1,685.7	924.2
Chlorfluazuron+5pb	61.8	23.5	251.0	103.6	113.4
Synergistic ratio	(2.6)	(2.6)	(2.8)	(16.3)	(8.2)
Synthetic pyrethroid					
Fenvalerate alone	5,790.0	—	—	5,409.9	—
Fenvalerate+5pb	522.2	—	—	268.4	—
Synergistic ratio	(11.1)	—	—	(20.2)	—

* Collection dates : HH (Oct. 6th, 1989); KW (Sept. 23rd, 1989); SC (Oct. 21st, 1989); IL (Sept. 23rd, 1989); LC (Dec., 1988)

teflubenzuron in three tested DBM populations, while the S. R. ranged from 2.6 to 16.3 for chlorfluazuron in five IGR-resistant DBMs (Table 1). The action of pb was also examined by testing fenvalerate resistance on two resistant populations. The synergistic effect of pb was proven positive and universal in DBM's resistance to currently commercially available IGRs in Taiwan.

3. The declining of IGR-resistance after releasing from the selection pressure

The DBM collected from LC-area in December, 1988 carried a high IGR-resistance, and the resistance magnitude were 7,621 and 243 folds for teflubenzuron and chlorfluazuron, respectively. In a period of 17 generations, the resistance declined to only 6.5 and 3.1 folds for teflubenzuron and chlorfluazuron, respectively (Fig. 2). The resistance decline for the EC formulation of teflubenzuron showed a similar trend.

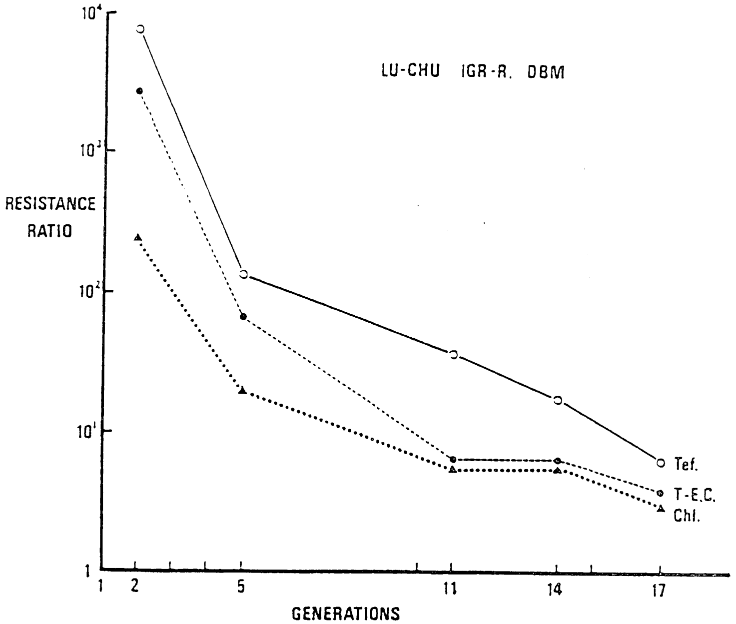

Figure 2. The decline of IGR-resistance of Lu-chu DBM in laboratory after releasing from the selection pressure.
Tef. : teflubenzuron, flowable powder
T-EC : teflubenzuron, emulsifiable concentrate
Chl. : chlorfluazuron, emulsifiable concentrate

4. Genetic tests of crossing the susceptible and two IGR-resistant strains

a. The reciprocal cross results of the susceptible and IGR-resistant DBM strains were presented in Table 2. In both tests, significant decrease in resistance was the only common conclusion, and the evidence of sex-linked (Russell, 1986) relation in IGR-resistance could not be found.

b. When the IGR-susceptibilities of the F_1-generation were compared to the probit lines of their parental strains (Figs. 3 and 4), significant increase in susceptibilities were found for both chlorfluazuron and teflubenzuron. If both compounds confronted with a common resistance, the genetic behavior of IGR-resistance would be considered as highly recessive.

Table 2. The reciprocal cross of the susceptible DBM and two IGR-resistant DBM strains for testing the possibility of sex linkage in IGR-resistance

Treatments	LC$_{50}$ in ppm			
	S*	S♂×R♀	S♀×R♂	R**
1st test				
Teflubenzuron	9.2	150.1	44.0	4,934.0
Resistance ratio	(1.0)	(16.3)	(4.8)	(536.3)
Chlorfluazuron	5.3	98.7	43.7	1,210.9
Resistance ratio	(1.0)	(18.6)	(8.2)	(228.5)
2nd test				
Teflubenzuron	9.2	22.1	35.7	209.4
Resistance ratio	(1.0)	(2.4)	(3.9)	(22.8)
Chlorfluazuron	5.3	36.3	96.9	162.0
Resistance ratio	(1.0)	(6.8)	(18.2)	(25.7)

* S : susceptible IL-strain (collected in 1983).

** R : resistant SC-strain for the first test (F$_3$).
resistant HH-strain for the second test.

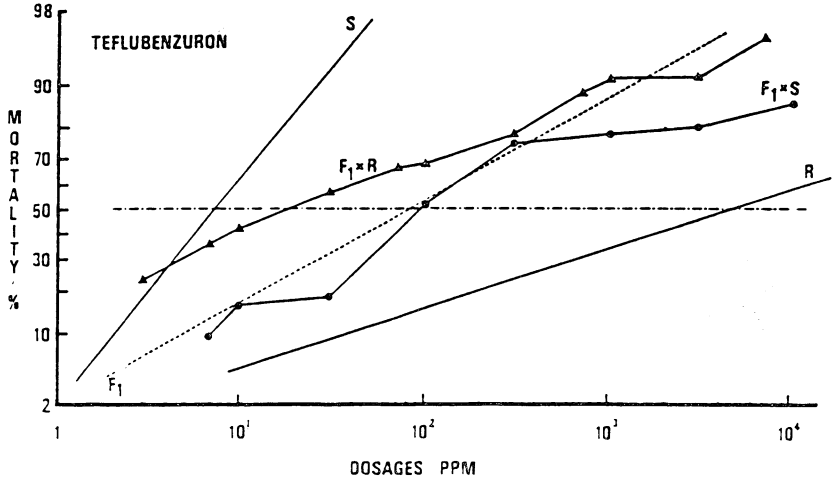

Figure 3. The teflubenzuron sensitivities of DBM in the susceptible (S), the resistant (R), the cross (F$_1$) and two backcross (F$_1$×R, F$_1$×S) strains.

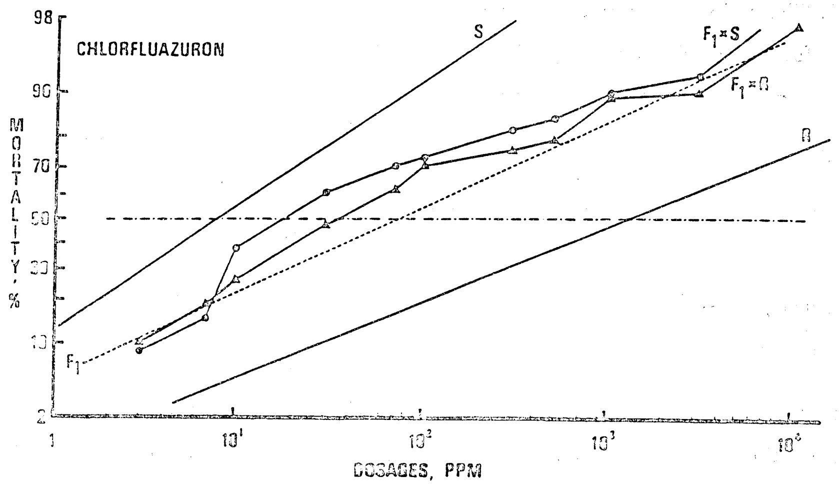

Figure 4. The chlorfluazuron sensitivities of DBM in the susceptible (S), the resistant (R), the cross (F_1) and two backcross ($F_1 \times R$, $F_1 \times S$) strains.

c. To test the monofactorial control of IGR-resistance, the IGR-susceptibilities were determined on the backcross of F_1 to the susceptible and resistant strains separately (Figs. 3 and 4). The results did not fit the suggested pattern of single gene control. The F_2 generation did not provided evidence to support the single gene control hypothesis either (Tsukamoto, 1983) (Figs. 5 and 6). The only conclusion could be made in these tests was that the IGR-resistance drastically reduced in all test crosses and continually declined as the generation proceeded. One problem related to this genetic test is that the degree of genetical homogeneity of the resistant strain. A better or clearer result would be obtained when a strain with only the homozygous IGR-resistance was used.

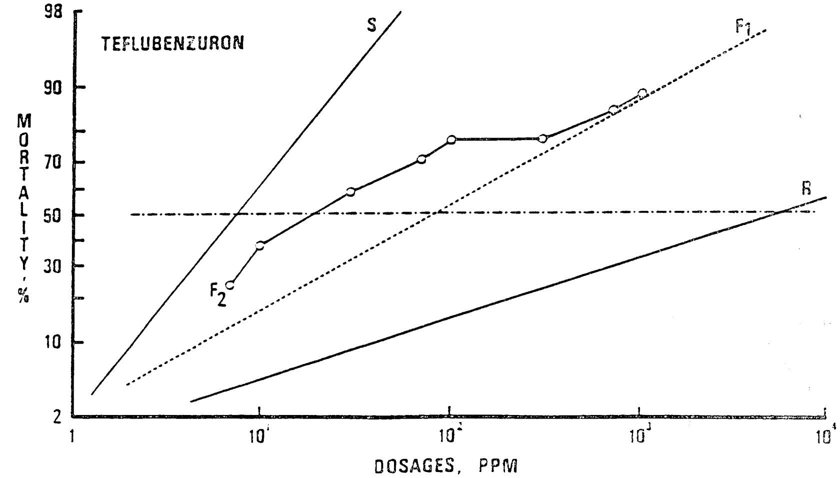

Figure 5. The self-cross (F_2) compared to its parental F_1, S and R-strains in their teflubenzuron mortality distribution pattern.

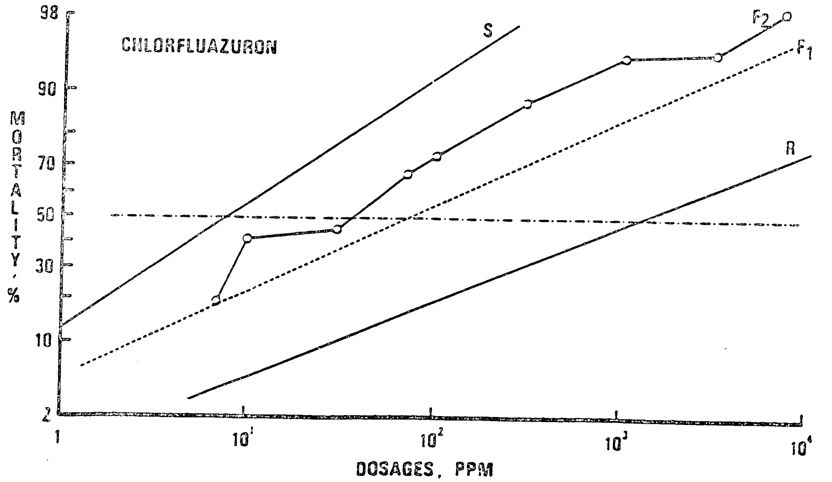

Figure 6. The self-cross (F_2) compared to its parental F_1, S and R-strains in their chlorfluazuron mortality distribution pattern.

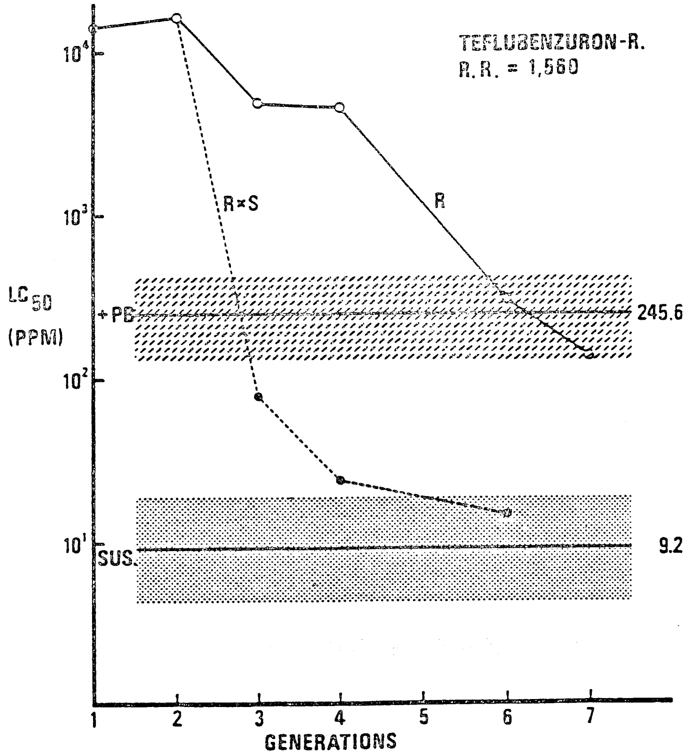

Figure 7. The teflubenzuron resistance decline (°)/accelated by crossing with the susceptible DBM (•)

LC50 (averaged from three tests of F1 to F5 of SC-strain with pb added) with range from 444.8 to 128.4 ppm

LC50 (averaged from 7 determinations of F59 to F77 of susceptible IL-strain) with range from 19.55 to 4.47 ppm

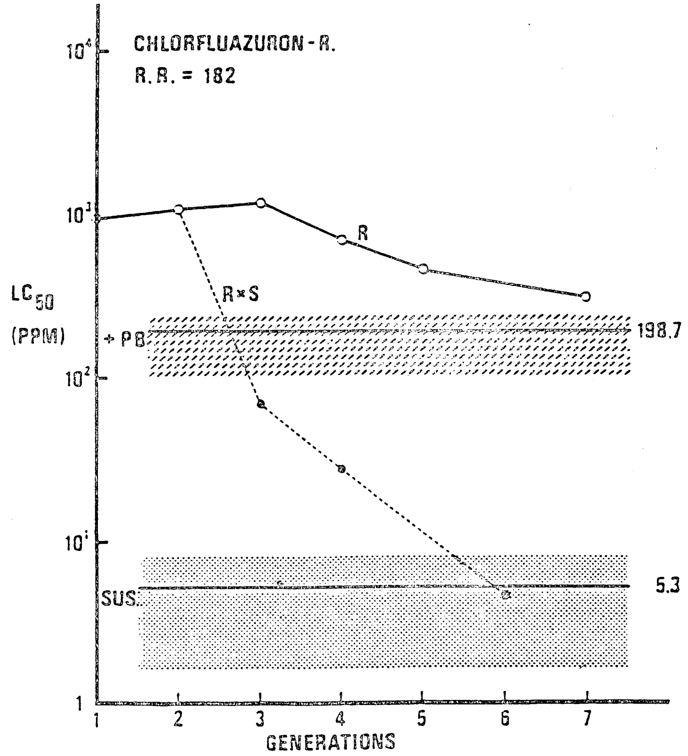

Figure 8. The chlorfluazuron resistance decline (°)/accelerated by crossing with the susceptible DBM (•)

LC50 (averaged from three tests of F1 to F5 of SC-strain with pb added) with range from 251.0 to 100.7 ppm

LC50 (averaged from 7 determinations of F59 to F77 of susceptible IL-strain) with range from 8.32 ppm to 1.68 ppm

5. Laboratory test for the possible management strategy of IGR-resistance

Through the genetic manipulation, we had observed the IGR-resistance of DBM could be greatly reduced by one cross with the susceptible strain. This genetic manipula tion already caused greater reduction in the IGR-resistance than the addition of pb. The sensitivity of teflubenzuron and chlorfluazuron with the addition of pb were determined in three tests from F_1 to F_5, and the values averaged at 245.6 and 198.7 ppm, respectively, and the ranges were 444.8 to 128.4ppm and 251.0 to 100.7 ppm in both cases.

The after-effect of this single cross on the teflubenzuron and chlorfluazuron-resistance (Figs. 7 and 8) was examined in the following generations and compared to the resistant DBM without such manipulation. In three more generations, the IGR-resistance in the offsprings of R×S population reduced to almost zero and the sensitivities to both teflubenzuron and chlorfluazuron were restored and equal to that of the susceptible strain, while the F_5-F_7 of the resistant strain was still 78 to 20 folds resistant to teflubenzuron and chlorfluazuron, respectively. The sensitivities to both teflubezuron and chlorfluazuron

in the susceptible strain were determined 7 times during F_{59}-F_{77}, and the average LC_{50} were 9.2 and 5.3ppm, respectively. The ranges of these determinations were indicated in Figures 7 and 8. The fact proved that by utilizing the recessive characters of IGR-resistance for genetic dilution, the decline of IGR-resistance can be speeded up.

Conclusions and discussions

Based on results of the field monitoring and the laboratory tests, several conclusions had been drawn on the characters of BTU-type IGR-resistance in DBM :

(1) Under intensive IGR spray without any alternation with other insecticides, the DBM can develop high resistance to IGRs rapidly. The span usually was less than one and half years or equal to 30 generations in the field, and the resistance level could reach more than thousand folds comparing to the original effective dosage. Eventually, the DBM simply became unaffected at any dosage.

(2) The metabolic degradation of IGRs in DBM is mainly attributed to the oxidation by mfo. The IGR-resistance in DBMs collected in Taiwan could be reduced by pb. The substrate affinity of this new mfo, which degraded teflubenzuron and chlorfluazuron, is independent from previously found mfos that degraded other pesticides such as synthetic pyrethroids.

(3) It has not been found that the IGR-resistance with any sex-lined character genetically.

(4) Genetically, the IGR-resistance is recessive or highly recessive. Whenever a resistant individual hybred with a susceptible counterpart, great reduction in IGR-resistance occurred.

(5) Once the susceptible factor, genetically dominant, has been re-introduced into a resistant DBM population, this susceptible factor will propagate naturally as the generation proceeds, and the whole population will re-establish its high IGR sensitivity promptly.

Chou and Cheng (1983) first reported that DBM can develop a new and highly specific factor to detoxify a particular insecticide as the carbofuran-resistant DBM was proven to act independently from methomyl and carbaryl. Thereafter, the specificity of mfo's detoxiacation in DBM had been recognized, and at least three lines of mfo which were separately responsible for the detoxication of synthetic pyrethroids, carbofuran and other carbamates were confirmed (Cheng et al., 1986). Before IGRs were commercialized in Taiwan, four IGRs had been studied in their mfo degradation in relation to effectiveness of the susceptible DBM. Indications of mfo degradation for the two non-effective IGRs did exist in DBM, while the naturally inherited mfo in the susceptible DBM could not utilize teflubenzuron and chlorfluazuron as their enzymatic substrate (Cheng et al., 1988). It had been proven that the degradation of diflubenzuron is mostly contributed to mfo in the housefly (Pimprikar and Georghiou, 1979). In the induced teflubenzuron-resistant DBM, the mfo was confirmed to be the major resistance mechanism (Perng et al., 1988; Lin et al., 1989). The significant role of this resistance mechanism for IGR was again confirmed in the general survey of IGR-resistant DBMs in Taiwan in this report (Table 1).

All those facts indicated DBM had a very efficient, active and inducible mfo system (or complex). Once the molecular structure of xenobiotic chemical was fit to be the substrate for one of the many hidden mfos, this sub-line of mfo will respond quickly to the selection pressure and a new type of resistance appeared. The problem is that when mfo become the responsible resistance mechanism, it would respond indefinitely or without any limitation in resistance amplitude, and rendered the control chemical useless at any dosage. Carbaryl, methomyl, carbofuran, synthetic pyrethroids, teflubenzuron and chlorfluazuron all encountered the same fate. The mfo system of DBM is very diversified, and it responded to the selection pressure of other experimental insecticide as well. For example, by selecting DBM with SN72129 (Cheng et al., 1987), a mfo that could metabolize SN72129 appeared.

When the resistance is genetically recessive, the selection pressure is needed to maintain the resistance in the population. By crossing the resistant strain with the susceptible strain, the immediate reduction of resistance in their offsprings can be obtained. This phenomenon had been demonstrated very well in the synthetic pyrethroids and many other insecticides (Liu et al., 1984; Cheng et al., 1988). By genetic manipulation, a recessive type of resistance is manageable if it does not intangle with the cross resistance from other insecticide.

The BPU-type IGR-resistance in DBM is recessive, selective and independent from other insecticide resistance. Under these conditions, the IGR-resistance of DBM in the field may become manageable if the sanctuary could be provided in field to harbor a portion of DBM population free from the IGR-selection, for example, mosaic sprays of IGR and *Bacillus thuringiensis* (BT) in alternate row or rows. Genetic dilution would occur when the survivors of mosaic spray mated. The environment will favor the prevention or delay the IGR-resistance naturally. The proposed sanctuary in a mosaic spray should be designed in a way to provide satisfactory mixing environment

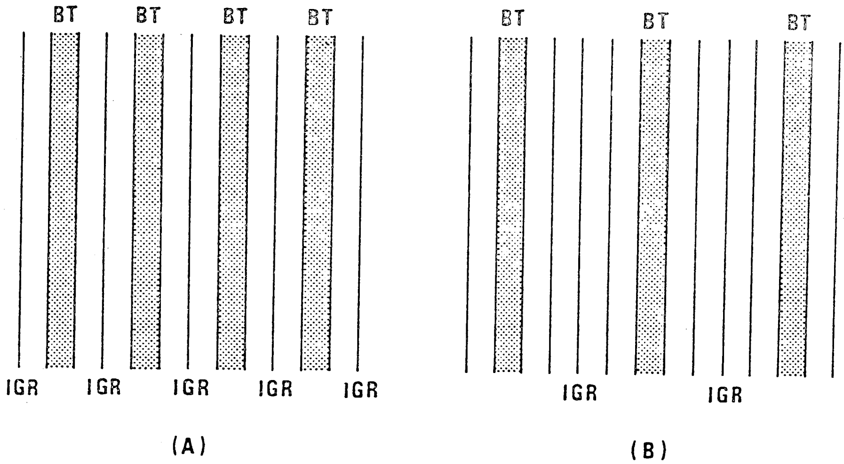

Figure 9. Proposed field mosaic sprays of IGR and BT. The survived DBM population in BT plots served as the susceptible strain to cross those DBM selected from IGR spray, and to delay or prevent IGR-resistance.

for DBM adults, which in turn may depend on factor like rate of dispersal of DBM adult (Fig. 9). The applicability of this strategy in what kind of field design will be the subject in our future study. Theoretically, the mosaic sprays of IGRs and BT is desirable for having minimum possibility in producing cross resistance and both insecticides favor the survival of natural enemies. Prosperous natural enemies, sanctuaries for the dominate susceptible gene, and two insecticides with independent modes of action and free from cross resistance should be considered as the most favorable combination in an integrated pest management (IPM) scheme.

If the IGR-resistance still slowly developed in IGRs and BT mosaic spray areas, insecticides such as mevinphos that cause only short-lived resistance in DBM (Cheng et al., 1985) can substitute as the control measure for a period of time to relieve the IGR-selection. The thorough study is definitely essential to construct a rational IPM implementation program to counter the resistance problem in DBM.

References

1. Cheng, E. Y. 1988. Problems of control of insecticide-resistant *Plutella xylostella*. Pestic. Sci. 23: 177-188.
2. Cheng, E. Y., T. M. Chou, and C. H. Kao. 1985. Insecticide resistance study in *Plutella xylostella* L. VI. An experimental analysis of organophosphorus and synthetic pyrethroid resistances. J. Agric. Res. China 34 : 96-104.
3. Cheng, E. Y., C. H. Kao, and D. F. Lin. 1987. The induction and the mechanism of SN72129 resistance in the diamondback moth, *Plutella xylostella* L. J. Agric. Res. China 36 : 228-236.
4. Cheng, E. Y., C. H. Kao, D. F. Lin, and T. C. Tsai. 1986. Insecticide resistance study in *Plutella xylostella* L. VIII. The specificity of oxidative detoxication mechanism in larval stage. J. Agric. Res. China 35 : 375-386 ·
5. Cheng, E. Y., D. F. Lin, T. C. Tsai, and C. H. Kao. 1988. Insecticide resistance study in *Plutella xylostella* L. IX. The selective metabolism of insecticides. J. Agric. Res. China 37 : 328-339.
6. Chou, T. M., and E. Y. Cheng. 1983. Insecticide resistance study in *Plutella xylostella*. III. The insecticide susceptibilities and resistance response of a native susceptible strain. J. Agric. Res. China 32 : 146-154.
7. Lin, J. G., C. F. Hung, and C. N. Sun. 1989. Teflubenzuron resistance and microsomal monooxygenases in larvae of the diamondback moth. Pestic. Biochem. Physiol. 35 : 20-25.
8. Liu, M. Y., J. S. Chen, and C. N. Sun. 1984. Synergism of pyrethroids by several compounds in larvae of the diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol. 77 : 851-856.
9. Perng, F. S., M. C. Yao, C. F. Hung and C. N. Sun. 1988. Teflubenzuron resistance in diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol. 81 : 1277-1282.
10. Pimprikar, G. D., and G. P. Georghiou. 1979. Mechanisms of resistance to diflubenzuron in the house fly, *Musca domestica* (L.). Pestic. Biochem. Physiol. 12 : 10-22.
11. Russell, P. J. 1986. Genetics. pp. 70-80. Little, Brown and Company, Boston.
12. Tsukamoto, M. 1983. Methods of genetics analysis of insecticide resistance. in "Pest Resistance to Pesticides", G. P. Georghiou and T. Saito (eds.), pp. 71-98. Plenum Press , New York and London.

13. Vattanatangum, A. 1988. Recent problems on chemical control of Thailand agricultural insect pests related to insecticide resistance of diamondback moth and other major species, in "Proceedings of Report Meeting of the Joint Research Project: Insect Toxicological Studies on Resistance and Integrated Control of the Diamondback Moth" pp. 8—13. Bangkok.

小菜蛾抗藥性之研究

十、昆蟲生長調節劑抗性特質及防治策略之探討[1]

鄭 允 高靜華 邱紀松[2]

摘 要

本省自1987年起，大量使用新登記之昆蟲生長調節劑（Insect Growth Regulator, IGR）防治小菜蛾以來，雖在田間僅使用一年半(相當於30個小菜蛾世代)，即已遭逢高達千倍之抗藥性。針對此一問題進行的研究得知，其抗藥性之機制爲一新誘發之氧化代謝酶，添加協力劑piperonyl butoxide（pb），可使此抗性之幅度下降。利用遺傳雜交試驗顯示，此一 IGR 之抗性無「性連遺傳」關係，且係隱性基因，利用雜交、回交及自交分析，皆未能得到與單基因控制理論相符合之結果，但此抗性主要爲隱性基因控制之事實已可確認。敏感品系在遺傳上具有顯性之優勢，將抗性族羣與感性族羣進行一次雜交即可造成 IGR 抗性之大幅下降，其幅度甚至超過添加協力劑之效果。雜交後再任其自交3－4代，全族羣對 IGR 之感度即已恢復，而與感性品系相當。引入感性品系對該抗性族羣之抗性下降幅度及速度均有促進之作用，此一特質可在未來之 IGR 抗性管理策略上加以應用，如保留部份間雜蔬菜區僅使用蘇力菌防治，以便在田間保護部份小菜蛾族羣不受 IGR 選汰，藉以保存在遺傳上占優勢之 IGR 敏感因子，可以自然雜交之方式延遲或阻止 IGR 抗藥性之發生。

關鍵詞：小菜蛾、抗藥性、昆蟲生長調節劑。

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Field Evaluation of Microbial and Chemical Insecticides for Diamondback Moth and Other Lepidopterous Pests Control on Cabbage[1]

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Abstract The newly introduced experimental *Bacillus thuringiensis* (BT) products and one synthetic chemical were screened in field on their efficacies to control the diamondback moth (DBM, *Plutella xylostella*), *Spodoptera litura* and *Pieris rapae*, and the long-used BT products and synthetic pyrethroids served as the comparing control agents. The results of two field experiments indicated that the newly commercialized SAN415-SC and other experimental BT products such as Florbac-FC, Florbac-XLV, TC0918 and CGA237218 provided better control on the DBM than other brands although suitable dosages still need to be determined. All BT products provided fair control for *P. rapae*. A newly developed thiourea insecticide/acaricide, Polo (diafenthiuron), performed better than any other entries in this field evaluation on both DBM and *S. litura*. Two tested synthetic pryethroids had not only lost their ability in controlling the DBM, also resulted in higher DBM counts by reducing both competition from other pests and the parasitization of natural enemies.

Key words : *Bacillus thuringiensis*, *Plutella xylostella*, *sodoptera litura*, *Pieris rapae*, diafenthiuron (Polo®)

Introduction

The diamondback moth is very efficient in developing resistance to various synthetic insecticides (Cheng, 1985; Cheng, 1988), and the control of multiple resistant DBM in field has become a difficult problem for vegetable farmers. Currently, only few insecticides registered on DBM in Taiwan (Taiwan Provincial Department of Agriculture and Forestry, 1990) show mild or no resistance problem, among those, BT is the most important one. Although suspected resistance to BT in lepidopterous species has been reported (McGaughey and Beeman, 1988; Kirsch and Schmutterer, 1988), it still remains to be clarified. On the other hand, the inconsistent control efficacy of BT is mostly linked to environmental factors (Ignoffo et al., 1982; Dunkle and Shasha, 1988; Dunkle and Shasha, 1989). In recent years, research on the improvement of BT efficacy has proceeded rapidly either by selecting mutants with higher potency or by combining

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the BT toxins to the BT formulations (Moar et al., 1986;McGaughey and Johnson, 1987; Padua et al., 1987; Gardner, 1988; Morris, 1988). For example, SAN-415 was introduced in Taiwan in 1989, and its DBM control efficacy in field was significantly better than other long-standing BT products (Chen, 1990). In order to compare the newly improved BT products and other recently developed chemicals on the control efficacy of DBM, experiments were conducted to evaluate and comment these experimental insecticides since they may be introduced for DBM control in Taiwan in the near future.

Materials and methods

1. Insecticides

A total of nine microbial and four chemical insecticides were used. The commercial formulations of three widely used BT were Thuricide WP (16,000 IU/mg, Sandoz Ltd.), Bactospeine WP (16,000 IU/mg, Duphar B. V.) and Dipel WP (16,000 IU/mg, Abbot laboratories). Six experimental BT formulations were SAN415-SC (8,000 IU/mg, Sandoz Ltd.), Florbac-FC (8,500 IU/mg, Duphar B. V.), Florbac-XLV (10,000 IU/mg, Duphar B. V.), Bactospeine-XLV (13,000 IU/mg, Duphar B. V.), TC0918 (10% a. i. in toxin, Cheng-Hong Chem. Co. Ltd.) and CGA-237218 (0.6% a. i. in toxin, CIBA-Geigy Corp.). Four synthetic chemicals used were 50% Polo SC (CIBA-Geigy Corp.), 50% Polo WP (CIBA-Geigy Corp.), decamethrin (2.8% Decis EC, Lansdowne Chem. Co. Ltd.) and flucythrinate (31.6% Pay-off EC, American Cyanamid Co.).

2. Field layouts and items inspected

Two field experiments were separately conducted from Dec., 1989 to Jan., 1990 and from Mar. to Apr., 1990, respectively to compare the efficacy of insecticides in controlling lepidopterous pests on vegetable. Field design of both experiments constituted 4 blocks, and 12 treatments were randomized into 4 blocks. Plots were separated by a protection row of cabbage. Insecticides were applied by hand-operated pressure sprayer and treated on a 7-day interval schedule. For the first field experiment, a total of 8 sprays were conducted, and insecticides were applied in 5 consecutive weeks in the second experiment.

The post-treatment inspections on target insects were made on the 6th day following each spray. Total number of larvae and pupae were counted on 10 plants randomly selected in each plot, and a total of 40 plants in four blocks were inspected for each treatment. In the first experiment, *Spodoptera litura* density was high and all 8 observations were reported. The population density of DBM was low in the first 3 applications, hence only the data from the 4th to 8th week were recorded for control efficacy analysis. In the second experiment, *Pieris rapae* occurred abundantly except the last inspec-tion, thus only the first 4 observations were analyzed. The control efficacy of DBM in each treatment were recorded and analyzed.

The control efficacy in percent was calculated by comparing the target pest count in each treatment to the check plots. The control rates obtained in each experiment were analyzed by Duncan's multiple range test at $\alpha=0.05$. When the target pest count was higher than that of the check plot, the control rate was set at 0%.

3. Examine the cross resistance on diafenthiuron

A multiple resistant DBM strain was compared to the susceptible IL-strain on their sensitivity to diafenthiuron. In this part of experiment, the synergist, piperonyl butoxide (pb), in 5 : 1 ratio to diafenthiuron was incorporated in the test. The testing method was identical to that of the previous report (Cheng et al., 1988).

Results and discussions

The results of the first experiment were presented in Tables 1 and 2 for DBM and *S. litura*, respectively. Results of the second experiment were presented in Tables 3 and 4 separately for DBM and *P. rapae*.

Table 1. The control efficacies of 11 insecticides on *Plutella xylostella* in the first field experiment (Dec. 1989-Jan., 1990)

Treatment	Dilution	% control					Mean*
		5 Dec	12 Dec	19 Dec	26 Dec	3 Jan	
Polo 50%WP	1000X	95.8	96.4	94.1	93.2	93.2	94.5 a
TC0918	1000X	87.5	89.3	79.4	95.9	87.7	88.0 ab
Polo 50%SC	1000X	66.7	92.9	76.5	97.3	95.9	85.9 ab
Polo 50%SC	2000X	66.7	82.1	91.2	91.9	89.0	84.2 ab
Florbac-XLV	667X	50.0	64.3	64.7	83.8	90.4	70.6 bc
SAN415-SC	1000X	41.7	71.4	64.7	90.5	56.2	64.9 c
Florbac-FC	571X	29.2	78.6	58.8	79.7	72.6	63.8 c
Bactospeine-XLV	889X	58.3	25.0	55.9	66.2	82.2	57.5 cd
TC0918	1500X	4.2	60.7	73.5	74.3	60.3	54.6 cd
Thuricide	1000X	25.0	39.3	50.0	68.9	35.6	43.8 d
Bactospeine	1000X	0	50.0	41.2	62.2	64.4	43.6 d

*Means followed by the same letter are not significantly different (α=0.05 ; Duncan's multiple range test).

Table 2. The control efficacies of 11 insecticides on *Spodoptera litura* in the first field experiment (Nov. 1989-Jan., 1990)

Treatment	Dilution	% control								Mean*
		14 Nov	21 Nov	28 Nov	5 Dec	12 Dec	19 Dec	26 Dec	3 Jan	
Florbac-FC	571X	86.2	73.6	85.3	96.1	96.2	86.7	77.3	66.7	83.5 a
Polo 50%SC	1000X	41.4	94.3	85.3	100	70.5	93.3	95.5	83.3	82.9 ab
Polo 50%SC	2000X	89.7	94.3	32.4	95.3	97.4	83.3	81.8	83.3	82.2 ab
TC0918	1500X	69.0	98.1	86.8	84.4	89.7	50.0	72.7	25.0	72.0 abc
Florbac-XLV	667X	44.8	56.6	82.4	89.1	92.3	70.0	68.2	50.0	69.2 abc
TC0918	1000X	0	96.2	55.9	89.1	79.5	63.3	77.3	83.3	68.1 abcd
Polo 50%WP	1000X	0	69.8	94.1	99.2	97.4	70.0	0	100	66.3 abcd
Thuricide	1000X	79.3	86.8	32.4	53.9	60.3	36.7	22.7	66.7	54.9 bcd
SAN415-SC	1000X	10.3	71.7	60.3	82.0	79.5	13.3	36.4	25.0	47.3 cd
Bactospeine-XLV	889X	0	43.4	30.9	64.8	74.4	20.0	22.7	66.7	40.4 de
Bactospeine	1000X	3.4	24.5	0	53.1	0	16.7	31.8	16.7	18.3 e

*Means followed by the same letter are not significantly different (α=0.05 ; Duncan's multiple range test).

Although the DBM density occurred in the two experiments differed due to variation in seasonal abundance, the outcome of treatments have similarity for a particular insecticide. Most of the entries of both field test were BT, but the control efficacy differed significantly from one product to another. Three currently available commercial BT products, Thuricide, Bactospeine and Dipel, did not perform as well as expected for DBM control. Among them, the long-used Bactospeine gave the worest performance in both field tests, and the control rate were 43.6 and 24.3% only. Another long-used BT, Thuricide, provided only 43.8 and 49.5% control.

On the contrary, new experimental BT products gernerally gave better DBM control at adequate application dosage. SAN415-SC, a new BT product on the market, provided 34—65% control, however another WG formulation with potency of 32,000 IU/mg provided better DBM control compared to other entries (Chen, 1990). For DBM, Florbac-FC and Florbac-XLV showed 64% and 60—70% control efficiencies, respectively, than the check plots, while TC0918 and CGA237218 gave 60—80% control (Tables 1 and 3). Although Bactospeine-XLV is a new BT formulation, only minimum improvement in its DBM control efficacy appeared.

Higher dosage of TC0918 and CGA237218 resulted in better DBM control. The dosage difference affected the control rate as the results varied between the two dosage treatments in TC0918 and CGA237218. It seems that for DBM, efficacies of Florbac-FC, Florbac-XLV, TC0918 (1000X) and CGA237218 (1000X) in field application were equal to or better than that of SAN415-SC (Table 1) .

Table 3. The control efficacies of 11 insecticides on *Plutella xylostella* in the second field experiment (Mar. Apr., 1990)

Treatment	Dilution	% control					Mean*
		27 Mar	3 Apr	10 Apr	17 Apr	25 Apr	
Florbac-FC	571X	46.4	64.5	64.2	70.7	68.1	62.8 a
CGA237218	1000X	57.1	60.9	55.6	57.1	73.9	61.0 ab
Florbac-XLV	667X	57.1	65.9	63.0	56.1	53.6	59.1 ab
Thuricide	1000X	42.9	60.1	33.3	44.7	66.7	49.5 bc
Bactospeine-XLV	889X	25.0	47.8	49.4	36.8	44.9	41.4 cd
CGA237218	2000X	27.4	46.4	46.9	43.9	14.5	35.8 de
SAN415-SC	1000X	22.6	28.3	22.2	47.2	47.8	33.6 de
Bactospeine	1000X	16.7	36.2	24.7	25.2	18.8	24.3 e
Dipel	1000X	29.8	22.5	19.8	36.6	8.7	23.5 e
Decamethrin	1000X	0	0	0	0	0	0 f
Flucythrinate	8500X	0	0	0	0	0	0 f

*Means followed by the same letter are not significantly different (α=0.05 ; Duncan's multiple range test).

Similar results were found for *S. litura*, which showed that Florbac-FC, Florbac-XLV and TC0918 were the better choice among BT tested in the experiment (Table 2). For *P. rapae*, all BT products gave similar and fair control which ranged from 57—78% (Table 4).

Table 4. The control efficacies of 11 insecticides on *Pieris rapae* in the second field experiment (Mar. Apr., 1990)

Treatment	Dilution	% control				Mean*
		27 Mar	3 Apr	10 Apr	17 Apr	
Thuricide	1000X	81.4	70.3	73.2	86.3	77.8 a
Decamethrin	1000X	88.5	75.5	70.4	72.5	76.7 a
Bactospeine-XLV	889X	64.6	70.3	88.7	76.5	75.0 ab
Florbac-XLV	667X	67.2	68.8	85.9	70.6	73.1 abc
Bactospeine	1000X	74.3	70.8	47.9	78.4	67.9 abc
CGA237218	1000X	61.9	75.0	59.2	74.5	67.7 abc
SAN415-SC	1000X	67.3	70.3	57.7	70.6	66.5 abc
Florbac-FC	571X	69.9	58.3	73.2	62.7	66.0 abc
Flucythrinate	8500X	68.1	53.1	69.0	64.7	63.7 abc
CGA237218	2000X	73.5	68.2	42.3	49.0	58.3 bc
Dipel	1000X	53.1	79.7	56.3	37.3	56.6 c

*Means followed by the same letter are not significantly different ($\alpha=0.05$; Duncan's multiple range test).

A new synthetic chemical, diafenthiuron, showed extremely effective control on both DBM and *S. litura*. The SC formulation performed equally well for both pest species, while the WP formulation was better on DBM than on *S. litura*. Diafenthiuron provided better and consistant control when compared to BT products(Tables 3 and 4).

As was reported by Cheng (1985), the DBM counts for both deltamethrin and flucythrinate treatments were higher than that for check plots, which demonstrated again that the synthetic pyrethroids had totally lost their ability to control the resistant DBM in Taiwan. The elimination in competition from other pests and the reduction of DBM mortality due to reduce natural enemies were presumed to be the reasons. This has been a common phenomenon in TARI's experimental farm in recent years(unpublished data of field evaluation tests in 1988 and 1989), although synthetic pyrethroids are still effective against other insect pests on cabbage (Chou et al.,1984).

Since diafenthiuron performed extremely well against DBM, it sensitivities of both the susceptible and the resistant DBMs were compared in the laboratory (Table 5). The results showed that the multiple resistant SC-strain (Cheng et al., 1990) had the same susceptibility to diafenthiuron as the susceptible strain i.e., LC_{50} at 245ppm, therefore, cross resistance from other insecticide does not exist. The addition of pb to diafenthiuron showed no difference in the resistant strain's sensitivity, which indicated that diafenthiuron may not be affected by the inherited oxidative metabolism in DBM.

Table 5. The laboratory test of diafenthiuron on *Plutella xylostella* for possible cross resistance from other insecticides

Insecticide or combination	LC_{50} in ppm		R. R. and S. R.**
	Suscep. strain	Resist. strain*	
Diafenthiuron	245.9	245.5	R. R. = 1
Diafenthiuron+5pb	—	240.8	S. R. = 1

*resistant SC-strain (Cheng et al., 1990)
**resistance ratio and synergistic ratio

References

Chen, W. S. 1990. Annual report on COA Projcet of the Management of Diamondback Moth. Tainan District Agricultural Improvement Station, Tainan, Taiwan, ROC (in Chinese).

Cheng, E. Y. 1985. The resistance, cross resistance and chemical control of diamondback moth, pp, 423-435. In Proc. lst Internat. Workshop on Diamondback Moth Management, N. S. Talekar (ed.), AVRDC Publication No 86-248. Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan.

Cheng, E. Y. 1988. Problems of control of insecticide-resistant *Plutella xylostella*. Pestic. Sci. 23 : 177-188.

Cheng, E. Y., C. H. Kao, and C. S. Chiu. 1990. Insecticide Resistance Study in *Plutella xylostella* L. X. The IGR-resistance and the possible management strategy. J. Agric. Res. China 39 : 208-220

Cheng, E. Y., D. F. Lin, T. C. Tsai, and C. H. Kao. 1988. Insecticide resistance study in *Plutella xylostella* L. IX. The selective metabolism of insecticides. J. Agric. Res. China 37 : 328-339.

Chou, T. M., C. H. Kao, and E. Y. Cheng. 1984. The occurrence of insecticide resistance in three lepidopterous pests on vegetables. J. Agric. Res. China 33 : 331-335.

Dunkle, R. L., and B. S. Shasha. 1988. Starch-encapsulated *Bacillus thuringiensis*: A potential new method for increasing environmental stability of entomopathogens. Environ. Entomol. 17 : 120-123.

Dunkle, R. L., and B. S. Shasha. 1989. Response of starch-encapsulated *Bacillus thuringiensis* containing ultraviolet screens to sunlight. Environ. Entomol. 18 : 1035-1041.

Gardner. W. G. 1988. Enhanced activity of selected combinations of *Bacillus thuringiensis* and beta-extoxin against fall armyworm (Lepidoptera: Noctuidae) larvae. J. Econ. Entomol. 81 : 135-141.

Ignoffo, C. M., C. Garcia, M. Kroha, and T. L. Couch. 1982. High-temperature sensitivity of formulations of *Bacillus thuringiensis* var. *israelensis*. Environ. Entomol. 11 : 409-411.

Kirsch, K., and H. Schmutterer. 1988. Low efficacy of a *Bacillus thuringiensis* (Berl). formulation in controlling the diamondback moth, *Plutella xylostella* (L.) in the Philippines. J. Appl. Entomol. 105 : 249-255.

McGaughey, Wm. H., and R. W. Beeman. 1988. Resistance to *Bacillus thuringiensis* in colonies of Indianmeal moth and almond moth (Lepidoptera: Pyralidae) J. Econ. Entomol. 81 : 28-33.

McGaughey, Wm. H., and D. E. Johnson. 1987. Toxicity of different serotypes and toxins of *Bacillus thuringiensis* to resistant and susceptible Indianmeal moth (Lepidoptera: Pyralidae). J. Econ. Entomol. 80 : 1122-1126.

Moar, W. J., W. L. A. Osbrink, and J. T. Trumble. 1986. Potentiation of *Bacillus thuringiensis* var. *kurstaki* with Thuringiensin on beet armyworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 79 : 1443-1446.

Morris, O. N. 1988. Comparative toxicity of delta-endotoxin and Thuringiensin of *Bacillus thuringiensis* and mixtures of the two for the bertha armyworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 81 : 135-141.

Padua, L. E., R. V. Ebora, and D. G. Moran. 1987. Screening of *Bacillus thuringiensis* against Asiatic corn borer, *Ostrinia furnacalis* (Guenee) and diamondback moth, *Plutella xylostella* (L.). FFTC Technical Bulletin No. 103, 7pp. Taipei city, Taiwan, Rep. of China.

Taiwan Provincial Department of Agriculture and Forestry. Plant Protection Manual, 1990 ed. Prov. Govn. of Taiwan, ROC. PP. 169-174 (in Chinese).

新型微生物及化學製劑防治抗性小菜蛾及其他鱗翅目害蟲之研究[1]

高靜華　邱紀松　鄭　允[2]

摘　要

針對本省抗藥性嚴重之小菜蛾及蔬菜上其他有關之鱗翅目害蟲，以新發展出之試驗性蘇力菌（*Bacillus thuringiensis*）製劑及殺蟲殺蟎劑硫化尿素（thiourea），進行田間藥效測定。結果發現，新發展之成品的確較以往之商品效果為佳，對小菜蛾、斜紋夜盜蛾之防治率均較固有之蘇力菌商品提高 50—100 %；而所有供試藥劑對白粉蝶之防治效果則略遜。蘇力菌製劑中，以 Florbac-FC、Florbac-XLV、TC0918、CGA237218 及 SAN415 之效果較以往使用之 Thuricide、Dipel及 Bactospeine 更佳。硫化尿素類之新藥 Polo（diafenthiuron）所表現之藥效更超過蘇力菌，惟此一化學藥劑未來可能遭遇抗性問題。Polo 之兩種劑型中，Polo-SC 對小菜蛾及斜紋夜盜蛾效果均佳，而可濕性粉劑配方對小菜蛾之防治效果則優於斜紋夜盜蛾。本試驗中再度證明，合成除蟲菊精類已對抗性小菜蛾完全失去防治效果，其試驗區內之小菜蛾密度甚至超過對照區，原因可能係該類藥劑不但未能造成小菜蛾之死亡，同時也減少其他害蟲與天敵對小菜蛾之競爭及寄生能力。

關鍵詞：蘇力菌、小菜蛾、斜紋夜盜蛾、紋白蝶、硫化尿素。

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絲瓜園扁蝸牛之發生與防治研究[1]

溫　宏　治[2]

摘要　扁蝸牛（*Bradybena similaris*（Férussac））為南部絲瓜園主要有害動物，食性雜、分佈廣。絲瓜園內主要分佈於支柱、地面及植株上。成蝸產卵於淺土內，約20～30粒為一堆。初孵化幼蝸為3螺層，成熟蝸為5～6螺層，蝸牛之體重受環境、氣候及食物之影響，以夏季最重，春、秋季次之，冬季最輕，扁蝸牛整年均可發生，其棲群密度由5月逐增，7月中旬達最高峰，10月後驟減，於絲瓜主幹及支柱地際部環施6％聚乙醛粒劑，可有效誘殺及阻斷扁蝸牛爬到植株上為害，且殘效持至21天。

關鍵詞：絲瓜、扁蝸牛、棲群密度、6％聚乙醛粒劑。

扁蝸牛（*Bradybaena similaris*（Férussac））又稱薄殼蝸牛，屬於軟體動物門（Mollusa）、腹足綱（Gastropoda），有肺目（Pulomonata），柄眼亞目（Stylommatophora），扁蝸牛科（Bradybaenidae）。分佈於本省、大陸、中南半島、韓國、日本、南、北美洲、太平洋及印度洋諸島、非洲等地[7,8]。屬雜食性，為害多種果樹[8]。近年來於本省南部普遍為害絲瓜及其他蔬菜，且該蝸牛於低溫乾旱環境，可潛於鬆土內或隙縫中，殼口分泌白膜自行封閉，借以抗爭不利氣候，待天氣適宜，隨即活動取食。據章及陳（1989）調查中部葡萄園扁蝸牛之出現和雨量有顯著相關，尤以下雨期為最，且果園附近雜草亦為其常出沒地方[3,6,9]。大致上其習性與蛞蝓及菲洲大蝸牛等軟體動物相近[1,4]，故田間時常發現它們共存在一處。據日人高橋氏[2]報告，於酸性土壤（缺石灰）加上濕氣重，為扁蝸牛發生之誘因，對於本省是否瓜園長期施用化學肥料導致土壤變酸，引起扁蝸牛之發生，值得將來深入探討研究，本試驗目的僅述扁蝸牛於絲瓜園之發生消長、活動及防治試驗，藉供防治與進一步研究之參考。

材料與方法

1.扁蝸牛不同季節重量比較

1988年1～12月，每個月於田間採回4～6螺層之蝸牛各30粒，分別稱其重量，以瞭解不同季節體重及其取食關係。

2.扁蝸牛於絲瓜園之分佈調查

1987年8月至1988年7月，每個月至屏東九如、里港地區調查扁蝸牛分佈情形，每次調查4區瓜園，每區採對角線逢機取樣100葉片、50根木柱及10個地面點，每點面積1平方公尺，計算所含成活之蝸牛數目。

3.扁蝸牛於絲瓜植株上之發生消長

1987年1月至12月於屏東縣九如鄉設一長期絲瓜調查園，園內不防治扁蝸牛，共植絲瓜 150株，每

1.臺灣省農業試驗所　研究報告第 1528 號，本研究試驗期間承本分所研究員李錫山先生諸多指教，植保系主任林正忠博士鼓勵，李明哲先生協助調查，文成後，承省農試所何琦琛博士斧正，謹誌謝忱。

2.本所鳳山熱帶園藝試驗分所助理研究員。臺灣省　高雄縣　鳳山市。

隔半個月調查一次，每株取樣老葉5枚，計算葉片上之蝸牛數目。

4.扁蝸牛之活動、靜止及死亡調查

1987年8月至1988年7月於調查扁蝸牛分佈時，同時記錄一試區扁蝸牛活動數（取食或行動者）、靜止數（殼口分泌白膜呈休眠狀態者）及死亡數（空殼或發出腐臭者），以瞭解其於田間存活情形。

5.防治試驗

1989年5～8月間於屏東縣九如鄉黃清號農友之絲瓜園進行藥劑防治試驗，試驗按逢機完全區集排列，將二分地瓜園劃分爲四區，每區爲一重複，每區複分5小區，每小區2畦，每畦5株。每小區爲1處理，共5處理，分別爲1.撒施6％聚乙醛粒劑於瓜園土面，每平方公尺施用量15克。2.環施6％聚乙醛粒劑於瓜株主幹及木柱地際部，每株或柱施用量15克。3.塗刷3.25％聚乙醛膏劑於主幹及木柱離地15公分處，每株或柱圍塗藥量 10c.c。4.環施3.25％聚乙醛膏劑於瓜株主幹及木柱地際部，每株或株用量15c.c。 5.不施藥處理。處理前先將已爬至植株或木柱上之蝸牛擲入地上，於處理後7日、14日、21日及28日，分別計算每瓜株上之蝸牛數作爲比較。

結果與討論

1.扁蝸牛不同季節重量比較

成熟扁蝸牛一般產卵於淺土內，卵通常爲20—30粒成一堆，卵孵化後幼蝸爬出土面，暫於地面腐草上活動，取食腐植物，幼蝸外殼具3螺層，成熟蝸爲5－6螺層，爬至植株上之蝸牛通常於夜間或陰天取食，可取食絲瓜各部分，以嫩梢、幼葉被取食最多，白天則藏於葉背，如遇環境不利時如冬天或乾燥時，呈靜止不食狀態，是故各季節所測的重量亦有差別。如表一所示，其重量均以夏季最重，秋、春雨季次之，冬季最輕。蓋夏季高溫多雨有利其活動取食，而冬季乾燥不利其活動，消耗養份，致使體重減輕。

表一、不同季節扁蝸牛之重量比較

Table 1. The weight of *Bradybena similaris* at different season (1988)

Seasons	Avg. temp. (C)	Weight of snail (g)		
		4 whorls	5 whorls	6 whorls
Spring	24.6	0.0642	0.0588	1.02
Summer	29.0	0.0762	0.0695	1.26
Autumn	28.3	0.0721	0.0678	1.14
Winter	20.5	0.0568	0.0497	0.89

2.扁蝸牛於絲瓜園之分佈調查

扁蝸牛屬雜食性，喜濕且耐乾旱，於絲瓜園內到處可見其蹤跡，更甚者有深入土內2～5公分處，其中以支柱、地面及植株上爲其主要分佈。由表二可知其分佈於葉片上，以8月份最多， 100葉平均達163.58隻， 2～3月份最少，僅2隻。地面上亦以8月份最多，每平方公尺達242.22隻， 3月份最少，僅182.6隻。木柱亦相同以8月份最多，每50木柱平均達423.22隻， 2月份最少，僅17.93隻。由此得知，扁蝸牛去年中分佈於絲瓜園各部位之起伏相當一致，均以8月份最多， 7月次之，而以2～3月最少。但無論於植株或木柱上均於4月份開始增加，是故發現扁蝸牛發生，應提早於

4～5月間開始作防治工作，避免6月份以後大量扁蝸牛爬至木柱或植株上，造成防治困難。

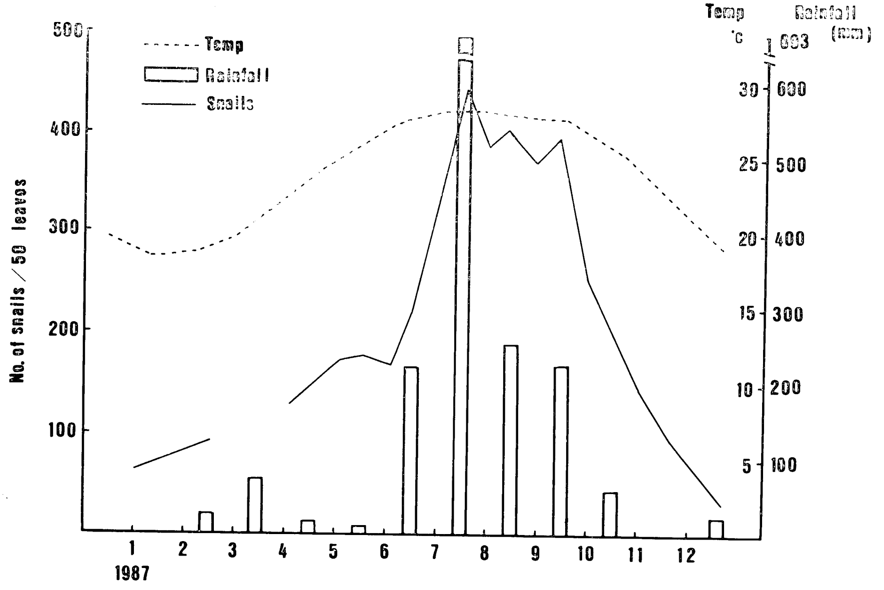
表二、扁蝸牛於絲瓜園之分佈（屏東）

Table 2. Distribution of *Bradybena similaris* in sponge gourd field at Pingtung area

Date	No. of *Bradybena similaris* by		
	100 leaves	Ground (1m^2)	50 wood holders
1987.8.28.	126.24	240.22	423.22
9.12.	158.32	123.40	160.73
10.28.	38.70	82.70	80.94
11.10.	32.55	57.34	158.57
12.15.	11.18	63.55	75.12
1988.1.2.	3.40	43.42	25.02
2.11.	2.70	22.34	17.93
3.14.	2.45	18.26	20.81
4.16.	12.21	30.22	34.57
5.16.	35.52	57.26	87.43
6.4.	139.67	97.34	153.26
7.15.	142.42	158.26	189.75
8.20.	163.58	225.32	375.48

3. 扁蝸牛於絲瓜植株上之發生消長調查

扁蝸牛在本省南部絲瓜植株上之消長，除受3月份試驗地休植缺調查資料外，其他月份均有發生，



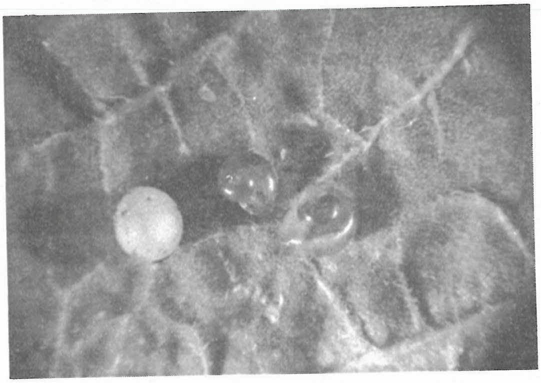
圖一、扁蝸牛於絲瓜植株之發生消長

Fig. 1. Seasonal fluctuation of Bradybaena similaris on sponge gourd.

但根據表二分佈調查情形，可斷定其整年均可發生。由圖一顯示，1月至2月氣溫低且乾旱，大部分蝸牛潛入隙縫中或淺土內靜止不動或死亡如表三所示，故植株上密度甚低，4月後氣溫回升，6月梅雨季節來臨，其密度因而逐漸增加，至7月中旬溫度最高，雨量最充沛，其消長達最高峰，10月以後雨量漸減，氣溫亦逐漸降低，蝸牛數量驟減。

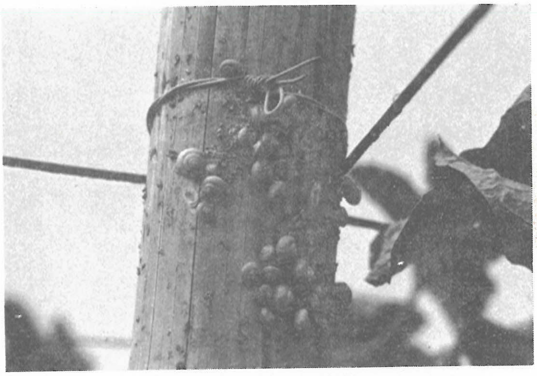
4.扁蝸牛之活動、靜止及死亡調查

扁蝸牛之活動由表三所示完全受溫度及雨量影響，溫度愈高、雨量愈大，其活動亦愈增強，如7、8及9月溫度均超過28°C以上，且雨量均超過 200mm 以上，大部分蝸牛呈活動狀態，其活動者占調查總數80%以上，10月以後溫度逐漸下降，雨量亦減少，活動漸弱，尤以冬季12月至次年2月平均溫度低於 20°C，且雨量稀少，其活動率低於 30%以下。4～5月後雨量漸增，溫度亦升，其活動逐漸頻繁。此結果與先前分佈調查（表二）及消長調查（圖一）頗吻合，是故由多項調查結果顯示夏季雨量充沛是扁蝸牛發生之關鍵因子。調查時發現部分扁蝸牛殼口結白膜，暫時靜止呈休眠狀態，藉以防低溫與乾燥氣候，靜止不動蝸數以10月份最多，占總調查蝸數 37.91%，12月及6月次之，8月份最少，僅占4.43%。由表三死亡率觀之，似乎與活動率呈相反，即活動率愈高其死亡率愈小，其因為冬季乾旱季節不利扁蝸牛之生存，其死亡（包括空殼及肉質發生異臭）量由11月逐增，1～3月達高峰，4月以後天候轉溫暖，逐漸有利其生存，死亡量減少。就整年觀之，扁蝸牛在



圖二、扁蝸牛之卵和幼蝸

Fig. 2. The egg and young snails of *B. similaris*.



圖三、扁蝸牛分佈於木柱情形

Fig. 3. *B. similaris* on the wood holder.

圖四、扁蝸牛食害絲瓜葉片

Fig. 4. *B. similaris* feeds on leaf of sponge gourd.

圖五、誘殺扁蝸牛情形

Fig. 5. Bait experiment to the *B. similaris*.

園中之活動率與死亡率有互補消長之現象。

表三、扁蝸牛於絲瓜園之活動、靜止及死亡比較

Table 3. Proportion of active, quescent and dead *Bradybena similaris* in sponge gourd field

Periods	Movable (%)	Quescence (%)	Death (%)	Temp (C)	Rainfall (mm)
1987.8.	87.78(732)*	4.43(37)	7.79(65)	29	245
9.	80.44(766)	10.84(103)	8.72(83)	28	224
10.	50.99(323)	37.91(240)	11.81(75)	28	96
11.	58.12(338)	9.58(56)	32.30(188)	25	3
12.	27.57(165)	17.84(107)	54.59(327)	19	21
1988.1.	27.37(94)	9.09(31)	63.54(219)	19	89
2.	23.76(54)	10.17(23)	66.07(150)	19	20
3.	31.37(102)	5.40(18)	63.23(205)	23	11
4.	65.14(275)	5.24(22)	29.62(125)	23	117
5.	67.91(244)	9.31(34)	22.78(82)	28	100
6.	64.97(338)	16.96(88)	18.07(94)	28	100
7.	82.90(528)	8.47(54)	8.63(55)	29	232

( )* Number of *Bradybena similaris*

5. 防治試驗

扁蝸牛主要產卵於淺土內，卵孵化後，幼蝸先於地面上活動，雨後沿植株主幹或支柱爬往植株上爲

表四、絲瓜園扁蝸牛之防治試驗

Table 4. Control of *Bradybena similaris* on sponge gourd field (1989, Jun.-Aug.)

Treatment	Snails/10 plants (Control rate)			
	7DAT*	14DAT	21DAT	28DAT
1. Metaldehyde 6% G 15g/m (Scattering on ground)	12.00a(80.3) **	17.50b(75.0)	49.80b(41.8)	83.20b(37.2)
2. Metaldehyde 6% G 15g/plant (dressing on bottom of trunk)	3.80a(93.8)	7.50a(89.3)	19.20a(77.5)	59.50a(55.2)
3. Metaldehyde 3.25% Paste 10 CC/plant (To plaster on base of plant)	9.80a(83.8)	23.80b(66.1)	41.00b(52.1)	85.60b(35.4)
4. Metaldehyde 3.25% Paste 10CC/plant (dressing on bottom of trunk)	14.00a(76.8)	18.00 (74.1)	55.30b(35.4)	97.40b(26.6)
5. Check (untreated)	60.25b(—)	70.00c(—)	85.50c(—)	132.00c(—)

* DAT : Days after treatment.

**Numbers followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

害，是故如何有效阻止扁蝸牛爬上植株爲害及殺死蝸牛爲本試驗之目的。由試驗結果表四得悉將6%聚乙醛粒劑環施於植株基幹及支柱地際處，可有效誘殺扁蝸牛，並防止爬至植株上爲害，其有效期可維持至21日。至於將6%聚乙醛粒劑散施瓜園土面與用3.25%聚乙醛膏劑塗刷於主幹基部或環施植株主幹或支柱地際部，其效果較差。

引用文獻

1. 伊賀幹夫。1982，アフリカマイマイの生態と防除，植物防疫。36(1)：21—28。
2. 高橋良一。1941，農作物お食害するオナツマイマ゛イ (*Bradybena similaris* Férussac) に就て。臺灣農事報。37：87—96。
3. 高橋良一。1984，關於食害農作物的蝸牛。臺灣農村2(8)：34—36。
4. 邱瑞珍、周根清。1978。非洲大蝸牛及其捕食性天敵。中華農業研究27(4)：363—371。
5. 張良傳。1962。蛞蝓之生活習性觀察及防治試驗。植保會刊4(1)：25—27。
6. 章加寶。1988。葡萄害蟲及其他有害動物種類及其季節消長。中華昆蟲8(1)：39—50。
7. 章加寶、陳武揚。1989。葡萄園扁蝸牛之形態及其生活習性觀察。植保會刊31(3)：217—224。
8. 羅幹成、邱瑞珍，1995。臺灣柑桔害蟲及其天敵圖說。臺灣農業試驗所特刊2.號：73。
9. Chiu, S. C., and K. C. Chou. 1962. Observations on the biology of the carnivorous snail *Euglandina rosea* Férussae. Bull. Inst. Zool. Academia Sinica 1 : 17-24.

Seasonal Occurrence and Chemical Control of *Bradybaena similaris* on Sponge Gourd

Hung-chich Wen

Summary

Flate snail (*Bradybaena similaris* (Férussac)) is a destructive animal on sponge grourd in southern Taiwan. Being polyphagous, its host range is wide and the population is distributed mainly on holders, ground and plant in the field of sponge gourd. After hatching, there were 3 whorls on the room of young snail and 5—6 whorls on mature snail. The weight of snail was affected by environmental conditions and foods, and was heaviest in summer, followed by autumn and spring next and lightest in winter. This snail occurred all year-round in southern Taiwan. Its population increased in raining season (May.-Sep.) and decreased in dry season (Oct.-Apr.). It was obviously affected by preciptation. Two snailicides were tested for the control of this snail in field. Application of Metaldehyde 6% G. on the bottom of trunk of plant and holders gave the best control on this snail in the field and could last 21 days.

Key words : Sponge gourd, Flate snail, population, Metaldehyde 6% G.

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落花生脫莢系統之改良[1]

梁連勝　蔡致榮　顏秀榮[2]

摘要　橫式排列之脫莢系統，應用在夾持式落花生收穫機，可消除直式平行排列脫莢設計在作業時，因脫莢死角所造成之株高限制與殘留問題；使落花生收穫機之作業性能獲得實質之改善，提高收穫機構對植株高度限制之因應能力，降低脫莢作業後之殘留率，使本收穫設計更實用化。

關鍵詞：落花生、脫莢。

農試型落花生聯合收穫機經本所技術轉移由合作廠商生產應市後，在示範及田間試驗中，研究人員發現其脫莢作業效果偶有殘留之原因，主要爲拔取時夾株偏離正常位置，脫莢時莢位落在平行脫莢設計之脫莢死角內所致。同時本設計對植株高度之適應性受到一無形之限制，即適收株高應在30公分以上，其作業效果方可達到原設計之預期結果，其主要原因乃爲脫莢死角有以致之。爲了改善平行脫莢設計之脫莢死角瓶頸，提高收穫機對植株高度限制之因應能力，降低脫莢作業後之殘留率，必需針對脫莢筒之排列方式重行予以規劃設計。

研究目的

消除原平行脫莢設計所衍生之脫莢死角問題，藉以提高農試型落花生聯合收穫機對植株高度限制之因應能力，降低脫莢作業後之殘留率，使本收穫設計之作業功能更趨穩定，並減少收穫作業時之田間損失。

研究方法

一、基本脫莢機構設計：

（一）脫莢筒排列與組合。
配合提高脫莢率之要求，重新規劃脫莢筒之組合與配置方式。

（二）脫莢筒中心位置之分析。
考慮莢果著生位置之變化，嚐試以不同之位差，達成完全脫莢。

（三）脫莢筒轉速與輸送速度分析。
以組間速度差，達成降低脫莢後殘留之要求。

（四）脫莢齒之排列與改良。
配合組間脫莢齒之嚙合定時與提高脫莢率，重新規劃脫莢齒之排列及齒型。

（五）動力系統
配合各組脫莢筒作業速度，規劃馬達動力傳導機構。

二、脫莢試驗與檢討

以不同脫莢供料速度及脫莢深度，進行脫莢試驗，分析脫莢效果。

三、試驗成果分析

根據試驗結果，利用電腦以統計程式進行分析。

1.臺灣省農業試驗所　研究報告第 1529 號。

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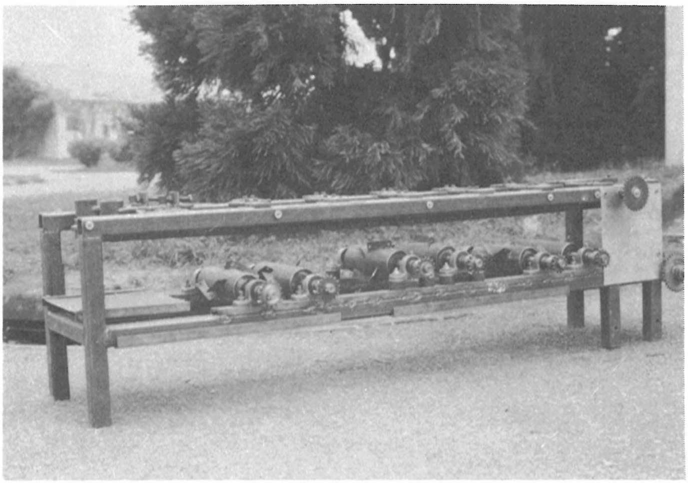
結果與檢討

一、基本脫莢機構設計：

本研究之試驗脫莢裝置包括脫莢筒組、兩側透明擋板、水平輸送帶、可調式供料台、組間集莢箱及動力系統，其全部機構如圖一所示。



圖一　橫式脫莢裝置及中心軸位差

（一）脫莢筒排列與組合

脫莢筒由原與脫莢輸送帶平行之排列，改爲與輸送帶垂直方向配置，以每兩筒爲一組，共使用三組。每組間以適當之間隙予以隔開。各組間分別以單一鏈輪或鏈輪組及鏈條作爲動力傳導機構，以輸入變速馬達之動力。

（二）脫莢筒中心位置之分析

各組脫莢筒之中心位置若採用等高度時，對不同植株夾持位置之脫莢效果，仍有輕微偶發之殘留發生。如使用第二組脫莢筒中心位置比第一、三組略高之設計時，脫莢時因組間有效脫莢高度之差異，使落花生莢果在脫莢作業過程中或因著生莢位不同，或因夾持位置之變化所生之實脫莢位置差之影響減至最小，使各脫莢筒組在脫莢作業中均能確實發揮脫莢功能。本研究脫莢筒組間中心位置之落差爲三公分，脫莢筒組與水平脫莢輸送帶之間隙爲4.5公分。

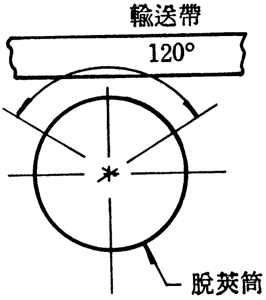
（三）脫莢筒轉速與輸送速度分析 [1,2,3,4,5,6,7]

每組脫莢筒採用段階增加之個別轉速，經脫莢試驗結果顯示，以 440R. P. M. ×500R. P. M. ×530R. P. M. 爲最佳組合—即馬達以220R. P. M. 運轉時，馬達與各組之鏈輪齒數比分別爲 34／17、34／15、34／14。各組內筒間之迴轉方向互爲反方向，即組中第一筒爲順時針方向迴轉，第二筒爲反時針迴轉。脫莢轉速採用段階增加設計之原因爲依據農試型落花生聯合收穫機田間試驗結果，對所有推廣栽培品種落花生之最佳脫莢速度爲 470R. P. M. ，故在第一組脫莢筒使用最低有效脫莢速度，可以脫落大部份之莢果並確保脫莢品質。在其後之第二、三脫莢筒組則使用較高之脫莢速度，此時因植株上餘留之莢果爲數無多，即使因採用高速脫莢造成較高之脫莢損傷，亦由於所佔比率不高而不影響整個脫莢品質，但卻可因此有效大幅降低脫莢殘留率。

水平輸送帶之作業速分別爲 100、120及 140R. P. M. ，進行脫莢試驗時其在各組脫莢筒組間之脫莢效果差異並不顯著，如表一所示。若水平輸送帶以120R. P. M. 轉速作業時其線速度爲0.75M/S，則各脫莢筒對輸送帶之相對速度分別爲：

第一組筒：前筒—4.78M/S、後筒—6.28M/S
第二組筒：前筒—5.53M/S、後筒—7.03M/S
第三組筒：前筒—5.91M/S、後筒—7.41M/S

假設植株自輸送帶下方計算之最低夾持高度爲25公分，每一脫莢筒之有效脫莢包夾範圍爲 120度（如圖二），



圖二 脫莢筒有效脫莢包夾角

輸送帶之速度爲每秒0.75公尺，則每一脫莢行程植株受脫莢齒作用之次數T可由式(1)來估算。

$$T = (S/V) \cdot N \cdot n \quad (1)$$

式中之S、V、N及n分別表示每一脫莢筒之有效涵蓋脫莢距離、輸送帶速度、脫莢筒轉速及每一迴轉脫莢筒接觸植株之次數。在本研究中脫莢筒之有效包夾角爲120度，則S＝0.12，每一脫莢筒裝配四組脫莢齒，故n＝4。將上述各值及脫莢筒轉速代入式（1），則每脫莢筒組對植株之脫莢次數分別爲4×2、5×2、及5×2；即每一脫莢行程之脫莢次數爲28。

各組脫莢筒在脫莢行程之脫莢量百分比經調查指出爲 86.5：13.2：0.3。第一組之脫莢量佔總脫

表一 水平輸送帶速度與脫莢深度於脫莢行程中對脫莢率之影響

輸送帶速度	脫莢深度	第一組脫莢率	輸送帶速度	脫莢深度	第一組脫莢率
0.63	18	86.2	0.75	12	88.0
0.63	18	85.2	0.75	12	84.5
0.63	18	93.7	0.75	12	84.7
0.63	18	88.4	0.75	12	90.3
0.63	18	92.8	0.75	12	84.7
0.63	12	82.4	0.88	18	88.6
0.63	12	79.0	0.88	18	83.9
0.63	12	90.1	0.88	18	89.8
0.63	12	89.6	0.88	18	91.2
0.63	12	76.4	0.88	18	90.4
0.75	18	78.5	0.88	12	83.6
0.75	18	96.9	0.88	12	87.7
0.75	18	86.8	0.88	12	79.7
0.75	18	91.9	0.88	12	96.1
0.75	18	85.0	0.88	12	71.2

莢量之86.5%爲最高。其脫莢結果如表一所示。若以使用深脫一即夾持位置爲18公分，其第一筒組之脫莢率較高，脫莢輸送帶速度差對其脫莢效率並未有顯著之差異，但對脫莢深度則有明顯之差別，如表二所示。

表二 脫莢深度對脫莢率之變方分析（95%）顯著水準

變異原因	平方和	自由度	均方	F 值	顯著水準
處理間	125.26	1	125.26	4.17	0.06
機差	841.66	28	30.06		

（四）脫莢齒之排列與改良

脫莢齒在筒上之裝配採用四組對稱之V字形排列，其夾角爲 120度。二齒互相交疊且相鄰二列之交疊方式正好相反，以便作業中植株不易由疊接處穿過或纏繞。每組脫莢筒間脫莢齒V字形之開口方向爲相反，即第一筒向後而第二筒向前。此設計之目的爲使植株系統在脫莢過程中因受脫莢之分散與集中作用，可有效錯開交錯之枝條，使夾在其間之莢果抖露出來，以減少殘留。爲確保脫莢效率並避免脫莢過程中植株偏離脫莢軌跡而漏脫，脫莢齒已經放爲寬10.5分，比原設計寬3公分。

（五）動力系統

試驗裝置之動力採用無段變速馬達，以鏈輪及鏈條作爲動力傳導機構，以應試驗時作不同速度變化之需。

討　論

使用橫式脫莢筒取代原平行脫莢筒設計，可解決原設計作業死角，但爲防脫莢時植株系統偏離脫莢軌跡，必需加寬脫莢齒。水平輸送帶與脫莢筒間隙應盡可能縮小，以提高各筒之有效脫莢包夾角。本設計之動力傳導較平行設計簡化甚多，且與輸送帶分開，可簡化齒輪箱設計。由於最佳脫莢深度範圍自12公分至18公分，故本設計之植株有效夾持高度應不小於20公分，如此在應用本設計時可使農試型花生聯合收穫機更適於本省各產區不同田間條件收穫作業之需。爲預防脫莢時偶有少量植株偏離而漏脫，建議將脫莢齒加大爲寬12.5公分，以爲因應。

參考文獻

1. 阮助明1987落花生打擊脫莢之基礎研究臺大農工所碩士論文　臺灣　臺北
2. 梁連勝、蔡致榮等1989夾持式落花生聯合收穫機之研製（I）中華農業　臺灣　臺中
3. 梁連勝1989落花生聯合收穫機之研製與試驗　臺大農工所碩士論文　臺灣　臺北
3. 黃文源、游勝秀1976小型迴轉式落花生脫莢機之研究中國農業工程學報Vol. 13(3)：40～47　臺灣　臺北
4. 矢治幸夫，我妻幸雄，今園支和1981落花生收穫作業の機械化に關する硏究　農事試驗場硏究報告35：207～234日本崎玉縣鴻巢市
5. Bulter, J. I., F. S. Wright and E. J. Williams 1970 Mechanism for Picking Peanuts from Oriented Plants Jour. of Am. Peanut Res. and Ed. Assoc. July 12-15：87～95 San Antonio, Texas, U. S. A.
6. Garner, T. H., et. Student Design of a Two-Row Direct Harvester for Peanut ASAE Paper No. SER-81-021 American Society of Agricultural Engineers, St. Joseph, U. S. A.
7. Mills, William T. 1961 New Method of Harvesting Virgina Bunch Peauts Transaction of the ASAE Vol. 4(1)：26-27, 30 American Society of Agricultural Engineers, St. Joseph, U. S. A.

Improvement of The Cross-Wise Picking System for Peanuts[1]

L. S. Liang[2], J. R. Tsay[3], S. R Yen

Summary

The crosswise picking system can be applied to eliminate the restriction of plant heights and the picking loss which result from the dead zone at picking area, as the parallel threshing device is used. It can promote the working efficiency of the TARI peanut harvester and makes the harvester more applicable for changes of the field feature.

Key Words : Peanut 、picking

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中華農業研究 (Jour. Agric. Res. China) 39(3)：239～257 (1990)

烏龍茶葉吸濕性及其品質維持之應用研究[1]

陳加忠　賴建洲　曹之祖[2]

摘要　在此研究中量測兩種烏龍茶葉的平衡相對濕度物性，實驗結果顯示電子式相對濕度計可適用於此種物性量測。溫度對等溫水份線的主要效應發生於70 RH%下範圍。修正Oswin模式適用於此項物性，此研究所得茶葉安定含水率範圍爲3－4％。自 GAB 模式計算所得之安定含水率數值顯著地高於來自 BET 模式之數值。利用量測的平衡相對濕度和溫度數值計算所得之含水率其誤差約爲0.5%。

關鍵詞：烏龍茶葉、吸濕性、單層水份、ERH模式。

茶葉的平衡含水率 (Equilibrium Moisture Content, EMC) 和平衡相對濕度 (Equilibrium Relative Humidity, ERH) 在不同溫度下的關係對於茶葉加工生產作業十分重要。有關乾燥、貯存、品質維持和包裝工作必須具備此物性之基本資料。然而茶葉此項物性之研究遠比其他農產品少 (Iglesias and Chirife, 1982), Wolf 等氏 (1973) 曾經發表三種茶葉 (Fennel tea, Kamillen tea, Pfefferminz tea) 吸濕和去濕之物性數據，其測定溫度爲5,25和45°C三種溫度，其測定方法爲動態法 (dynamic method) 。Jayaratnam與Kiritisinghe氏 (1974) 發表20°C 時碎茶的 ERH/EMC 數值方法爲EMC靜態法。在日人的研究中， Yoshinomi (1985) 以靜態法完成了茶葉原料 (未加工) 茶梗和葉片在四個溫度下的吸濕和去濕數據。對本省此項物性的研究中，茶改場曾對煎茶、包種茶、烏龍茶和碎型紅茶在固定單一溫度下的 ERH/EMC 性質提出有關數據 (阮與吳氏，1979) 。但是本省主要茶葉產品在主要應用溫度範圍下有關數據未曾有詳細之研究。各不同品種或製造方法對此物性之影響亦缺乏相關資料。

在農產品加工作業中，以簡單的數學模式代表不同溫度下平衡含水率和平衡相對濕度的關係十分重要。主要的適用模式必須能包含含水率，相對濕度和溫度等三項因子，而且涉及的參數數目愈少在實際利用上愈方便。農產品主要適用的 ERH/EMC 模式可歸納爲四種 (Chen, 1988) 。在上述茶葉平衡相對濕度和平衡含水率的有關數據中。本省四種茶葉之適用模式僅涉及 BET 公式之計算 (阮與吳，1979) ，其應用範圍不廣。日人 Yoshitomi (1985) 的研究結果曾比較5種模式的適用性，但只提及各固定溫度下的模式適應性而未考慮溫度項目之影響，因此適用本省茶葉ERH/EMC性質之模式實有研究之必要。

茶葉品質之保持對於茶葉之售價影響極大，依傳統製茶業之經年經驗，茶葉最佳之貯存含水率爲3～4％，此數據存在學理上之物理意義實有探討之必要，以做爲決定其他農產品最佳貯存含水率之用。

在此研究中，以依序農產品平衡相對濕度測定法 (Chen, 1988) 量測兩種不同製造方法之烏龍茶葉產品在5種溫度下的ERH/EMC物性，並探討適用此項物性之模式。在品質維持應用研究方面，以

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量測之數據決定單層水份量之值和業者長期經驗之數值比較，並探討 ERH 性質在茶葉含水率探測之應用。

理論探討

一、農產品內水份的存在現象

水份存在於農產品內的活動現象是影響農產品品質的主要因素， 通常以四個階段代表 (Young and Nelson 1976)。

乾的農產品表面存有無數毛細管，置於潮濕的環境時，水分子開始聚集於表面（圖1－a）。隨著水份的增加，在細胞上形成一單層水份子覆蓋於表面（圖1－b），此時水分子自身之間和分子與細胞之間的吸附能量最大，再次隨著水份的增加，多層的水分子開始推疊於單層水份子之上（1－c），此種水份可稱自由水（free water），係以擬聚作用堆附於單層水分子之上，在吸濕的最後階段中

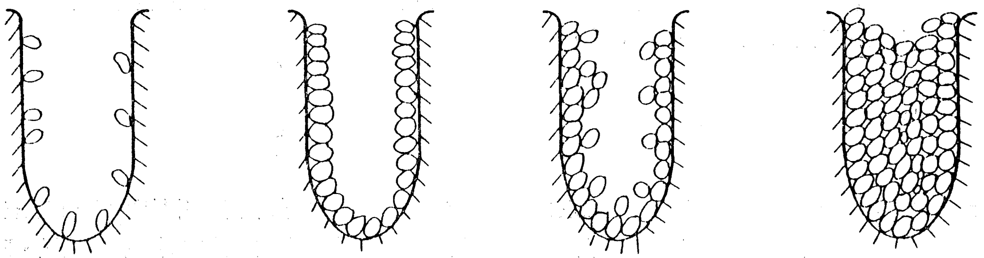


圖 1. 存於農產品內部水份子之吸濕現象

Figure 1. The sorption of water molecular existing in the inter of agricultural products

，水份子因毛細管作用吸附於多層水分子（圖1—d），由於此吸附力十分微弱，此時之水份也因此容易失去。各階段的水份分佈現象影響了農產品品質，然而各階段農產品的含水率卻不容易加以區分。

由食品化學反應速率的研究中，發現食品在某一含水率時其品質之損失幾乎爲零，此種含水率稱爲「安定含水率」或「關鍵安水率」(Critical moisture content) (Labuza 1984)，此含水率與單層水份值相等。此由圖 (1—b) 可以理解：在分子細胞表面聚集水分子時，一方面阻止了外界因素與農產品表面接觸以產生化學反應。另一方面由於水分子量少而缺乏活動性，所含水份不足以成爲溶劑以溶化化學物質，因此缺乏活動性而無法開始化學反應。因此食品在此安定含水率時，其品質可維持最佳情況。

二、ERH模式

在此研究中，以各溫度下茶葉ERH/EMC數據，比較各 ERH 模式的適用性，所利用的含三參數模式和含四參數之模式其推衍過程已詳細介紹於陳氏等人之研究（1990）。在此研究中所利用的模式爲：

（一）修正Henderson公式

$$RH = 1 - EXP\ (-A*(T+C)*M^{B}) \quad (1)$$

（二）Chung-Pfost公式

$$RH = EXP\left[-\frac{A}{T+C}\exp(-B*M)\right] \quad (2)$$

（三）修正Halsey公式

$$RH = EXP[-EXP(A+BT)*M^{-C}] \quad (3)$$

（四）修正Oswin公式

$$RH=\frac{1}{\left(\frac{A+BT}{M}\right)^{c}+1} \quad \cdots\cdots (4)$$

（五）Day-Nelson公式

$$RH=1-Exp[-aT^{b}\cdot M^{CT^{d}}] \quad \cdots\cdots (5)$$

（六）Kumar-Henderson公式

$$RH=1-EXP[-(a+bT)M^{(c+dT)}] \quad \cdots\cdots (6)$$

（七）Chen-Clayton公式

$$RH=EXP[-aT^{b}\cdot EXP\ (CT^{d}M)] \quad \cdots\cdots (7)$$

（八）Andrien-Oswin公式

$$RH=\frac{1}{\left(\frac{a+bT}{M}\right)^{c+dT}+1} \quad \cdots\cdots (8)$$

在以上的公式中，RH代表相對濕度，數值爲小數，M爲含水率（%，乾基），T爲溫度（°C）。

三、BET與GAB模式

在食品科學界最常利用的ERH模式爲BET和GAB模式。

BET模式由三個研究者Brunauer, Emmett 與 Teller (1938) 聯合推導而得。此模式對水分子存在於農產品內部之性質有兩項假設：（一）在多層水分子中每吸收層蒸發的速率等於凝結的速率。（二）在第一層單份子以上之各層分子其凝結熱都相等。

BET的公式如下：

$$\frac{RH}{(1-RH)\cdot M}=\frac{1+(C-1)RH}{M_0C} \quad \cdots\cdots (9)$$

在此C爲常數，M_0爲單層水份子數值。

由於此公式受其基本假設之限制，其適用範圍並不能遍及所有 RH 的範圍 (0～100%)。在食品科學的研究中，M_0 值代表單層水份子分佈於農產品內部所有表面時之含水量，換言之，農產品之含水率在此數值時其品質處於最穩定狀態。Labnza 氏 (1984) 率稱此 M_0 值爲關鍵含水率 (Critical moisture content)。

利用公式 (9) 對ERH/EMC數據進行迴歸分析，以RH/(1-RH)・M值爲反應值，RH 爲獨立變數，以直線迴歸所得截距與斜率線和之倒數即爲M_0值。此計算方式有兩項限制：

（一）大量且準確的ERH/EMC數據不容易獲得。

（二）不同的RH應用範圍將得到不同的M_0值。BET模式適用的範圍不容易界定。

爲了改良BET模式之限制，GAB模式逐漸爲食品研究者採用。此公式之推衍過程近似 BET模式 (Van den Berg, 1984, 1985) ，其形式爲：

$$M=\frac{M_0\circ C\cdot K\cdot RH}{(1-K\cdot RH)(1-KRH+K\cdot C\cdot RH)} \quad \cdots\cdots (10)$$

此公式中M_0值爲單層水份子數量，C與K爲常數。K＝1時，公式(10)與BET模式相等。

在公式(10)中M值爲反應值，RH爲獨立變數，若以RH值代表爲M之函數，公式(10)之函數轉換則成一複雜的公式。

$$RH=\frac{2+(M_0/M-1)\cdot C-[[2+(M_0/M-1)\cdot C]^{2}-4(1-C)]^{0.5}}{2*K*[1-C]} \quad \cdots\cdots (11)$$

四、利用RH與溫度量測值計算含水率

由農產品平衡相對濕度和溫度之量測值配合已知之等溫水份線之關係 ， 含水率可依此計算而得。

Hughes等式（1965）利用Licl Dunmore-type感應器量測麵粉的平衡相對濕度值，藉以計算其含水率。Gough氏（1976）以空氣抽取技術量取小麥穀粒間隙內空氣的平衡相對濕度和溫度，再計算其含水率，在以上兩者的研究，此技術之精密性並無詳細討論。Bunn 等氏（1986）以此種技術計算玉米粒和大豆的含水率，量取的RH和溫度值以ASAE標準中修正Henderson 公式計算含水率。其結果顯示含水率愈高的樣品其誤差愈大。

此種含水率的測定方法十分簡易且快速，但是其準確性不容易控制。Young氏（1983）對此技術評論如下：

（一）含水率，相對濕度與溫度三者之關係需要建立正確適用的模式。

（二）在進行量測時，量測對象必處需於平衡狀態。

（三）在高RH階段，RH的少量量測誤差會引起含水率計算值鉅大的誤差。

（四）RH值本身的量測誤差通常很大。

五、預測性能的評估

在數量化的研究如農機作業系統模擬，病蟲害預測……等，模式的驗證十分重要。其意義即在於檢驗經由數量化模式所得的預測值和實際之量測值是否相符合，研究者通用的方法是將兩種數值描繪於同一張圖形而以感官直覺觀察數據之符合性。此種方法容易受主觀因素限制，而且受X-Y軸之間隔大小所影響；反之，利用統計理論爲基礎的量化標準並不普遍（Teng and Gaunt, 1980; Teng, 1985）。

依現代迴歸分析之理論和技術（Myers, 1986）模式之預測性能可依定量和定性兩種檢驗方式。應用此方法之基本假設在於模式之預測值和檢驗用量測值必須互爲獨立性，即模式建立所利用之數據與檢驗用量測數據彼此互不相同。

（一）定性檢驗

以模式之預測值和實際之量測值各爲 X－Y軸加以描繪數據散佈圖，若兩者相符合，則數據點必須分佈於X＝Y，斜率爲1的直線。在實際的作業情況，此理想狀態幾乎不存在。 在實際應用中，若符合性成立，誤差之存在非存在於模式自身，而僅由測誤差所引起，在此情況下描繪殘差值對實測值（或預測值）之數據分佈，將爲一均衡分佈且無特定趨向之圖形。此方法是用以檢測模式是否正確的最佳定性標準。

（二）定量檢驗

利用統計理論之 t 分佈性質可做爲檢驗模式符合性的量化依據。

1.平均偏離差（Average Deriation, AD）

AD值之計算公式如下：

$$AD = \Sigma \mid Yi - Xi \mid / N \cdots\cdots\cdots\cdots \quad (12)$$

Y_i：實測值

X_i：預測值

N：數據總數

AD值愈小，符合性愈佳。

2.含常數項迴歸的檢定法：

以所有Y_i值和X_i值進行迴歸分析，線性迴歸公式 $Y_1 = a_1 + b_1X$ 之兩係數 a 與 b 其數值和標準差（S. E, Stundard error）容易計算，若yi之預測性能良好，b 值應該與0無顯着差異，值與1無顯著差異。因此利用 t 分佈原理之檢驗方式如下：

$$t'(a_1)=\frac{a_1}{SE(a_1)} \cdots\cdots (13)$$

$$t'(b_1)=\frac{b_1-1}{SE(b_1)} \cdots\cdots (14)$$

由 t 分佈表可檢驗tt′(a_1) 與t′(b_1) 值是否顯著。

3.不含常數項之迴歸檢定法：

在線性迴歸技術中，不含常數項的直線迴歸其基本假設即截矩值爲零，此種假定對模式之驗證有其特殊意義。在比較$y_2=b_2X$與$y=X$直線是否相異之檢定值爲：

$$t'(b_2)=\frac{b_2-1}{SE(b_2)} \cdots\cdots (15)$$

材料與方法

一、烏龍茶葉

在此研究中所用之實驗材料爲條狀烏龍茶葉（文山型）和團狀烏龍茶葉（鹿谷型），分別購自不同之茶商，樣本最初含水率約於3～5%的範圍（乾基），爲得到不同含水率之樣本，材料以乾燥或加水方式調製至預定的含水率。所有的材料置於塑膠瓶內密封貯存兩個月以上以求樣本含水率之均勻化，高含水率的樣本容器則置放於3°C之冷藏庫內以避免霉菌成長。

二、平衡相對濕度測定

在此研究採用依序平衡相對濕度測定法，此方法已詳細介紹於稻穀此項物性之研究（陳、賴、曹，1990）。測定所用之感應器爲 VALSALA Humidity Transmitter HMD 30UB。 測定溫度自5～45°C共五種。

三、模式適稱性之研究

兩種烏龍茶葉所測量之 ERH, EMC 和溫度數據以非線性迴歸技術最小平方法評估含三參數之ERH模式適稱性，四種模式爲修正Henderson公式，Chung-Pfost，修正Oswin與修正 Halsey公式。團狀烏龍茶葉所測量數據用以比較參數數目對於模式適稱性之影響， 所利用之四參數模式爲 Day-Nelson, Kumar-Henderson, Chen-Clayton, Andrieu-Oswin 公式。 模式適稱性之評估標準在定性方面爲殘差圖，定量標準所用統計量爲 R^2, S. E., P，與RMS 值，各統計量的定義和計算公式都與稻穀ERH模式之評估方法相同（陳等，1990）。

BET模式之評估問題在於適用 RH 範圍的界定，此研究中利用殘差圖，離羣值（Outliers）與影響點（Influence Point）之檢定法以界定此適用範圍。

各溫度下GAB模式各參數之評估值估算利用非線性迴歸最小平方法加以執行。

四、烏龍茶葉含水率之計算

爲使烏龍茶葉含水率之檢定試驗與預測模式之建立過程彼此獨立。此測定所用之樣本與平衡相對濕度測定所用樣本並無重覆性。所用茶葉來自不同茶葉供應商。樣本經乾燥或加水至預定之不同含水率程度，再貯存於容量250ml塑膠瓶內，貯存時間在一個月以上以求其達到平衡狀態。

在測定過程中，以能同時測定溫度和相對濕度之感應器於樣本容器之中，在15分或20分鐘後讀出溫度與相對濕度值，RH值讀出以校正方程式轉換爲眞實值。再將溫度和 RH眞實值代入適用之 ERH模式計算含水率，茶葉之標準含水率利用烤箱以105°C 進行24小時烘乾作業加以量取。兩種數值依統計技術加以比較。

此種測定所用之感應器爲Rotronic Hygroskop GT-S Sensor由瑞士製造。

結果與討論

一、烏龍茶葉平衡相對濕度性質

團形烏龍茶葉平衡相對濕度的吸濕性質如圖2所示，圖形的分佈為典型的S型曲線。在相同的含水率時，ERH 值隨溫度的增加而增加，但主要之效應在於70% RH 的範圍之內。此種溫度效應遠小於澱粉類穀物之ERH性質 (Chen, 1988)

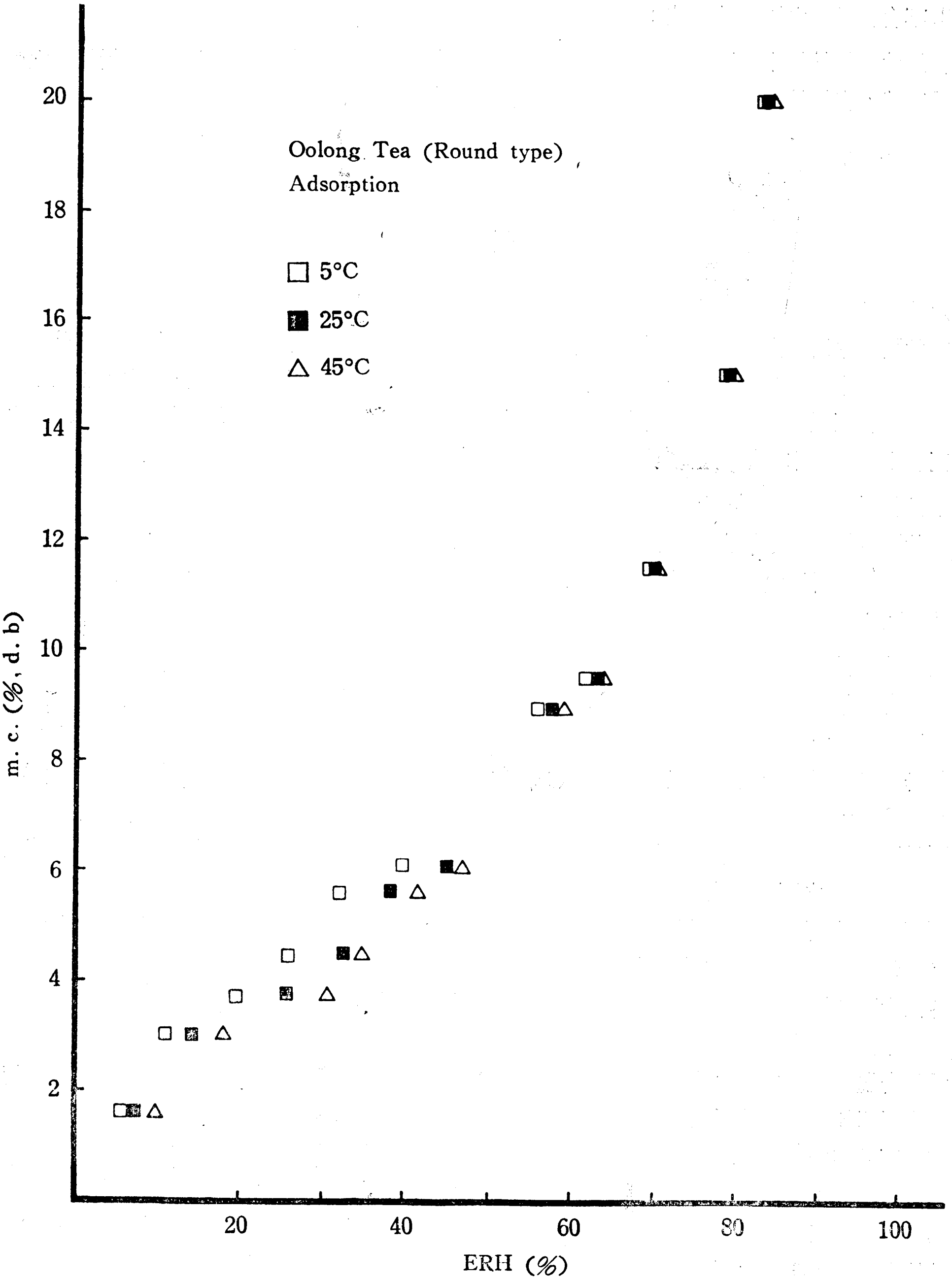


圖 2. 團形烏龍茶葉之吸濕數據

Figure 2. The adsorption data of round-type Oolong tea

條形烏龍茶葉此項物性性質如圖3所示，等溫水份曲線則近似指數函數圖形。主要的溫度效應發生於70% RH以下的範圍。

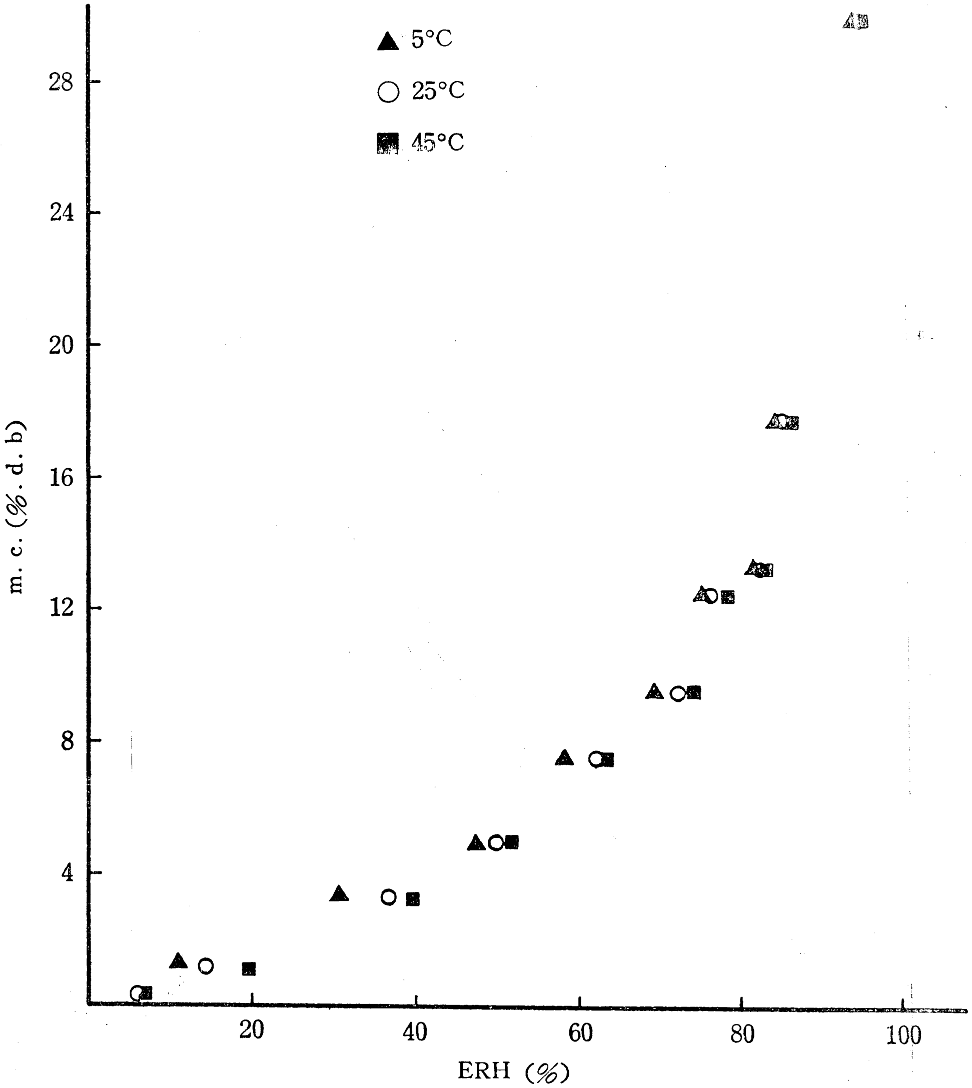


圖 3. 條狀烏龍茶葉之吸濕數據

Figure 3. The adsorption data of stripe-type Oolong tea

此次實驗所得兩種烏龍茶葉平衡相對濕度之物性與其他文獻所列結果之比較如圖4所示。在相同的溫度和平衡相對濕度條件下，團狀烏龍茶葉其所能吸收的水份大於條狀烏龍。各種不同茶葉產品等溫水份線的分佈性質差異極大，在相同條件下，Fenchea tea之樣本其吸收水份特別高於其他產品。其他產品在相同溫度與相對濕度條件下，含水率之差異性範圍約爲2%。因此各種不同品種或製造過程所得的茶葉產品其平衡相對濕度有個別測定的必要。在傳統平衡含水率測定法的利用中，由於其耗時繁雜的工作使個別測定十分麻煩，利用新開發完成「ERH 依序測定法」可以於短時期內得到大量準確的數據，因此適合進行此種多樣產品的測定工作。

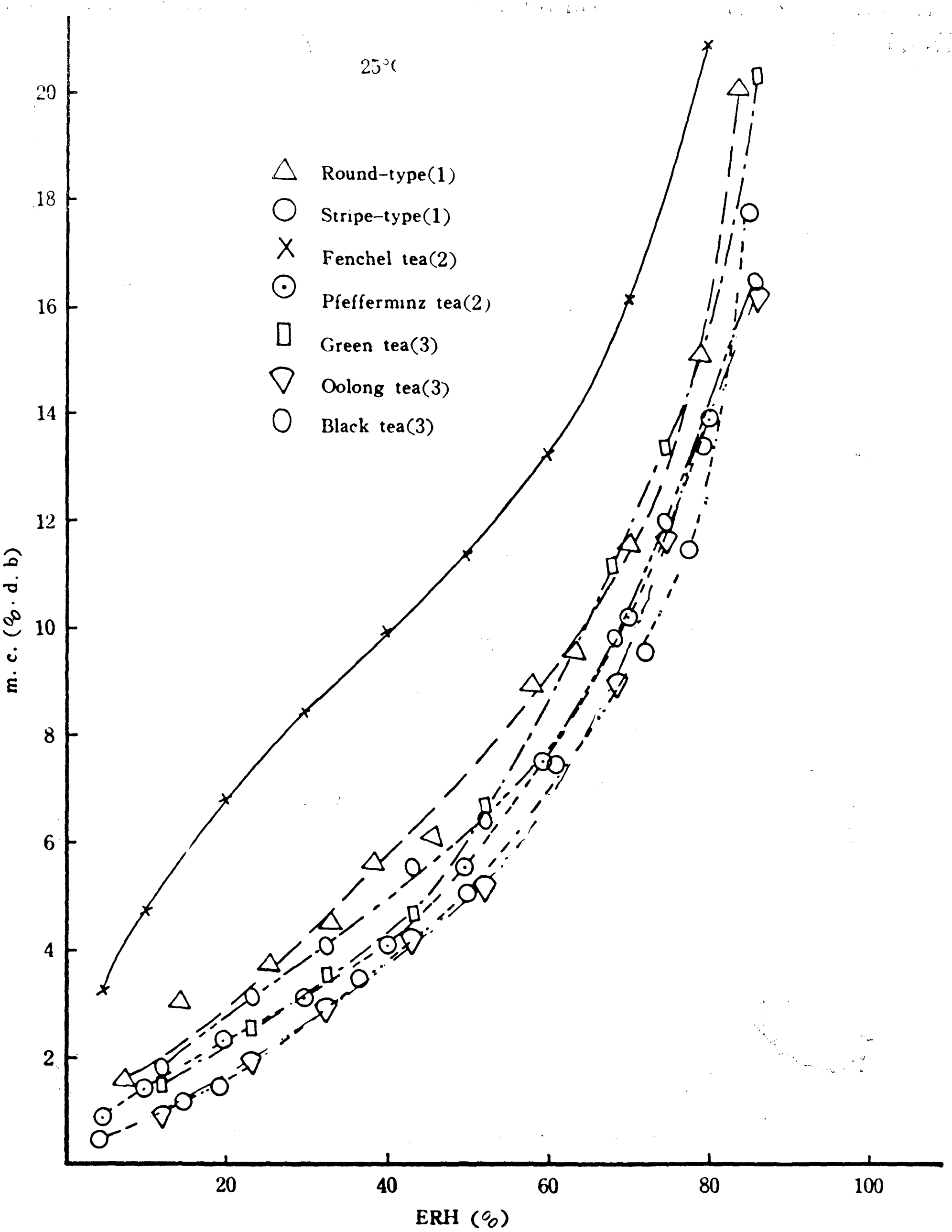


圖 4. 各烏龍茶葉ERH數據之比較

Figure 4. Comparison of the ERH data of Oolong tea
Data source : 1. Tsis experiment
2. Wolf et al. (1973)
3.阮與伍氏 (1979)

茶葉之吸濕物性與其他農產品此項物性之比較如圖5。圖中之茶葉產品數據爲此研究所測定之條狀烏龍茶。由圖形之分佈可知，茶葉的吸濕性在低 RH範圍時低於含高澱粉類（水稻和玉米粒）和高

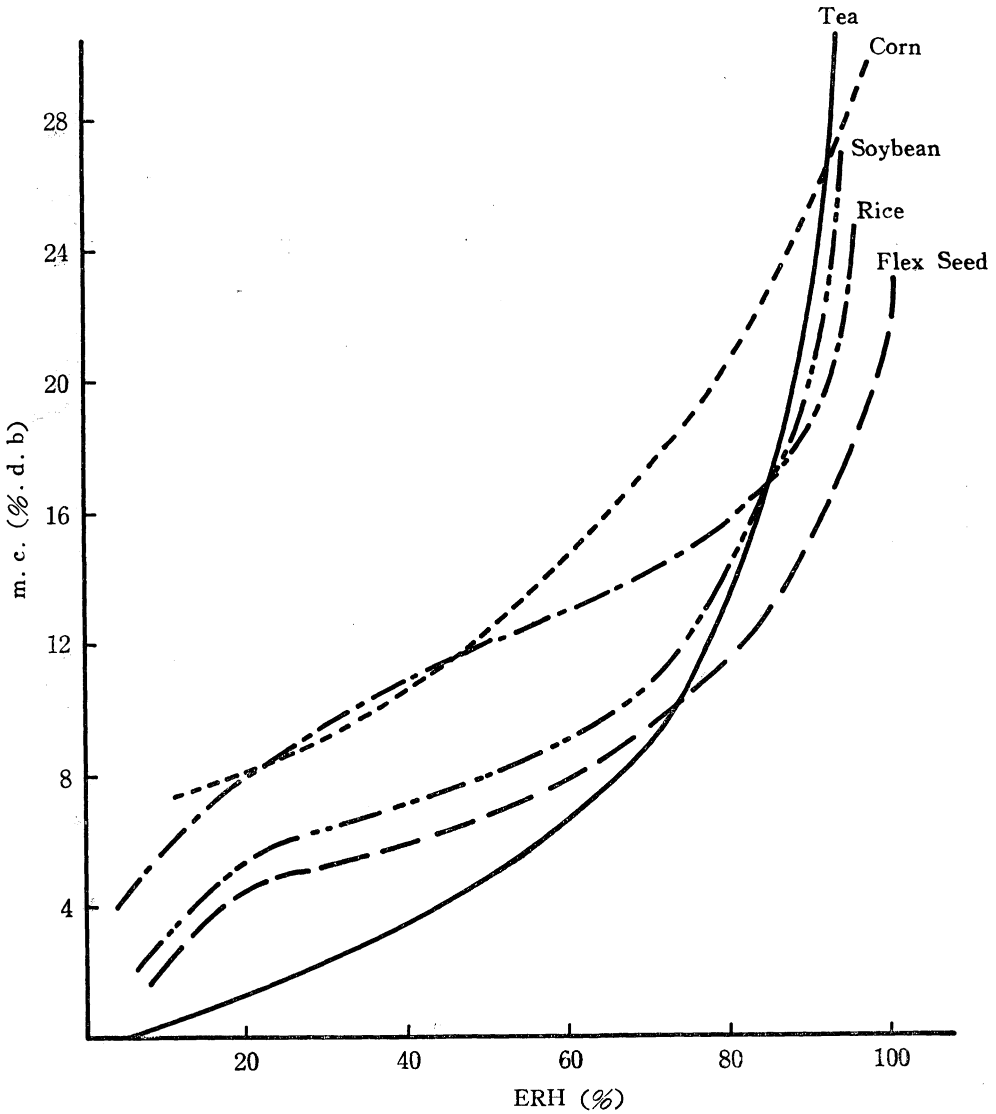


圖 5. 烏龍茶葉與其他農產品ERH數據之比較

Figure 5. Comparison of ERH data of Oolong tea with Other products
(Data source: ASAE Standards)

蛋白，油類（大豆，亞麻種子）等產品。在70% RH階段，茶葉的吸濕性急速的增加，其能吸收的水份則高於其他產品。

二、適用模式之評估

四個含三參數的 ERH 模式其對團形烏龍茶葉平衡相對濕度物性適用性之比較和估計值列於表一。由表中可知修正Oswin模式之S. E. 值較小，但是P和RMS較大。因此可知以單一量化標準評估模式之適用性並不可靠，由殘差分佈中（圖7b），在低RH範圍修正 Halsey 公式誤差性大，因此P值和RMS也隨之增加，由於茶葉吸濕性質之應用如品質維持，含水率測定和包裝材料評估等均位於低 RH 階段，在實際應用之考慮條件下，修正 Oswin 模式較適合爲團狀烏龍茶葉之物性模式。

條狀烏龍茶葉此項物性適用模式之評估結果如表 2 。依殘差分佈檢驗結果修正Henderson與修正

表 1. 團烏龍茶葉吸濕數據四ERH模式之估計係數和比較標準

Table 1. The estimated parameters and comparison criteria for four ERH models of adsorption data for Oolong tea of round type

	Modified-Henderson	Chung-Pfost	Modified-Oswin	Modified-Halsey
A	6.630 E—5	519.572	8.34235	1.85774
B	1.0621	0.16593	—2.3443 E—2	—4.6637 E—3
C	1,198.55	181.30	1.7669	1.1038
R	0.966	0.949	0.983	0.988
S. E.	4.91	6.05	3.44	2.69
P	13.6	14.1	6.81	7.71
RMS	26.5	27.4	9.34	15.5
Residual Plot	Pattern	Pattern	U. S. (Uniform Scattered	U. S.

表 2. 條形烏龍茶葉吸濕數據四ERH模式之估計係數和比較標準

Table 2. The estimated parameters and comparison criteria for four ERH models of adsorption data for Oolong tea of strip type

	Modified-Henderson	Chung-Pfost	Modified-Oswin	Modified-Halsey
A	1.23042 E—5	369.245	5.54496	1.04536
B	0.88093	0.18504	—2.5449—2	—5.466 E—3
C	1,280.85	153.004	1.27133	0.85794
R	0.991	0.967	0.993	0.978
S. E.	25.2	69.8	9.77	24.2
P	9.83	22.2	5.98	13.6
Residual Plot	U. S.	Pattern	U. S.	Pattern

Oswin公式均可適用，兩者統計量比較結果可知修正Oswin公式爲最適用的模式。

模式參數數目對於適用性的影響如表3所示，所利用之吸濕相關數據爲團形烏龍茶葉。由此結果可知，模式自身之適稱性比增加參數數目更爲重要。以根源於Henderson的三模式（修正 Henderson, Day-Nelson, Kumar-Henderson公式）而言，其適稱性並未比修正 Oswin 公式好。四參數之模式其殘差分佈趨勢均和三參數之模式相同，其原因在於參數之增加並未改變原先模式的分佈趨勢，對於源於Chung模式之兩模式亦有相同的結果。在量化標準方面，四參數的Chen-Nelson模式其P和RMS値反而高於含三參數的 Chung-Pfost 模式。對源於 Oswin 模式而言，含四參數的Andrieu-Oswin模式其適稱性則比修正Oswin模式更好。

表 3. 團形烏龍茶葉吸濕數據八個ERH標式適稱性之比較

Table 3. The comparison of the fitting-agreement for eight models of Adsorption data (Round-type Oolong tea)

Original Equation	Henderson Equation			Chung Equation		Oswin Equation	
	Modi.-Henderson	Day-Nelson	Kumar-Hnederson	Chung-Pfost	Chen-Nelson	Modi.-Oswin	Andrieu-Oswin
A (a)	6.6308—5	3.5555 E—2	5.9253 E—2	519.572	3.6372	8.3424	7.91922
B (b)	1.0621	2.4420	8.7449 E—4	0.1660	−0.1305	—2.3443E—2	−2.7903 E—2
C (c)	1,198.55	1.3628	1.1510	181.3	0.18676	1.7669	0.55125
(d)		− 7.079 E—2	−3.4092 E 3		−4.9195E—2		2.07998 E-3
R	0.966	0.968	0.969	0.949	0.949	0.983	0.992
S. E.	4.91	4.78	4.78	6.05	6.05	3.44	2.45
P	13.6	11.33	12.44	14.12	14.52	6.81	4.84
RMS	26.5	20.97	23.7	27.42	28.90	9.34	8.67
Residual Plot	Pattern	Pattern	Pattern	Pattern	Pattern	U. S.	U. S.

三、M_0值之計算

單層水份值（M_0）的計算在決定品質維持最佳含水率時十分重要。對團狀烏龍茶葉而言，5種溫度下其 ERH/EMC 數據公式（9）進行迴歸分析，並以殘差圖，離羣值和影響點檢定技術以決定 BET 模式之適用範圍，由統計分析結果顯示BET模式在團狀烏龍茶葉等溫水分吸濕線之適用範圍為60%RH 以下。迴歸所得之截矩，斜率和依此計算所得之（M_0）值列於表 4。

以相同統計技術對於條狀烏龍茶葉五種溫度等溫水份吸濕數據進行分析，BET 模式之適用性也在60%RH以下。

表 4. 團形烏龍茶葉單層水份值之計算

Table 4. The Calculation of monolayer value of rough-type Oolong tea

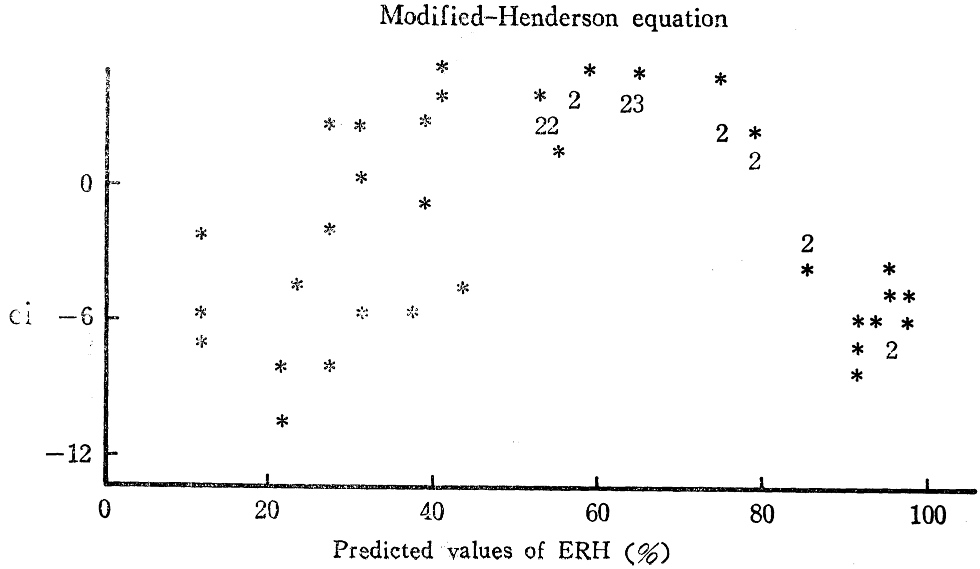
Item／Temperatare (°C)	5	15	25	35	45
Slope	2.24196	0.24081	0.2320	0.2277	0.21427
Intercept	0.01528	0.02033	0.0277	0.03325	0.04296
Mo	3.887	3.831	3.850	3.830	0.890

兩種烏龍茶葉依BET模式計算所得 M_0值比較於表 5。團形茶葉之數值略高條形茶葉。M_0 值均與周圍溫度無相關性，且皆位於 3 ～ 4 %之範圍。此數值與茶葉製作者多年所得之經驗相符合，亦驗證了 M_0 值在農產品品質維持上的學術背景和應用意義。換言之，在此安定含水率條件下所貯存的茶

表 5. 兩種烏龍茶葉BET模式之單層水份值

Table5. The Monolayer values for BET model of two type Oolong tea

Temperature (°C)	5	15	25	35	45
Round-type Oolong tea	3.89	3.83	3.85	3.83	3.89
Stripe-type Oolong tea	3.55	3.36	3.73	3.51	3.46



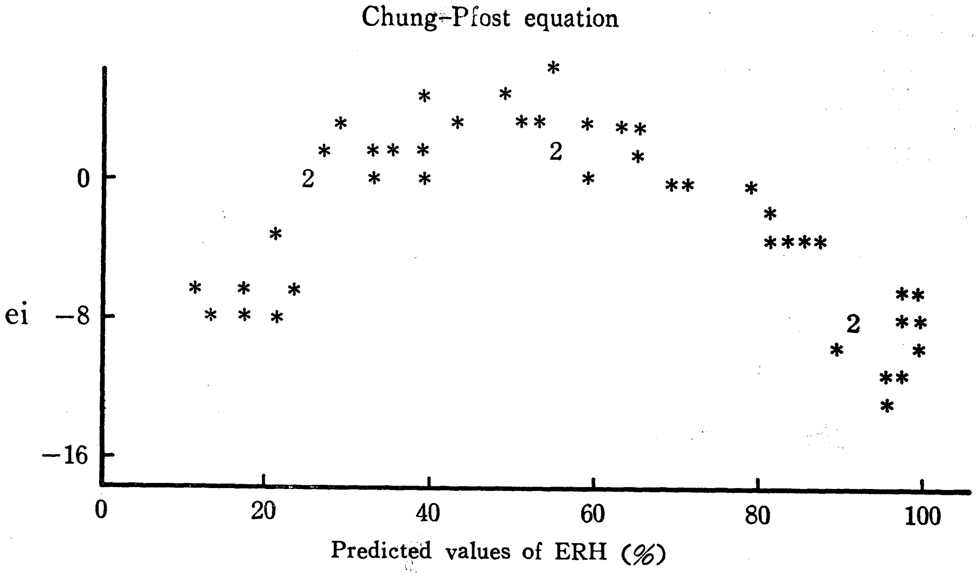
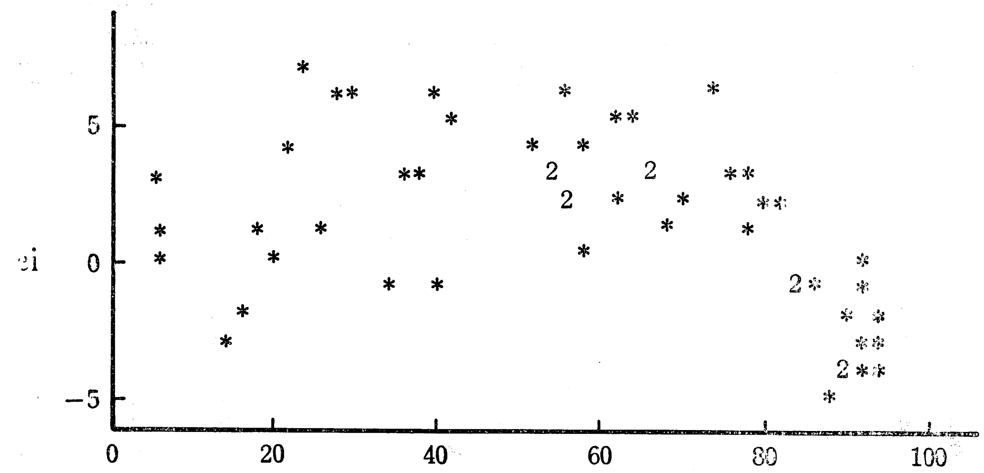


圖 6 團形烏龍茶葉吸濕數據各ERH模式之殘差圖

Figure 6a. Residuals vs. predicted values of ERH models for adsorption data of round-type Oolong tea



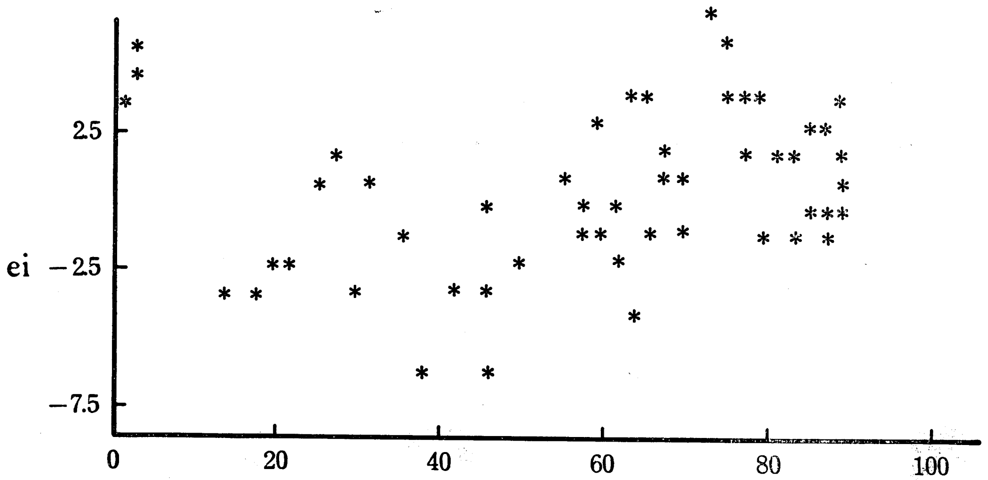


圖 6b 團形烏龍茶葉吸濕數據各ERH模式之殘差圖

Figure 6b. Residuals vs. predicted values of ERH models for adsorption data of round-type Oolong tea

茶其風味、香氣……等品質之損失最低。此M_0 值之計算和推廣更可適用於各種乾料食品（如香菇）和中藥藥材以保持藥性之貯存。在 M_0值爲 3 — 4 %時。其對應相對濕度約於 30～35%之間，因此在以平衡相對濕度爲品質指標時，其值爲30%～35%，此與 Labnza (1984) 之建議值（ERH＝30%）十分接近。

以GAB模式進行各溫度下ERH/EMC數據之適用性評估，其結果如表 6,7 所示，由GAB 模式所得單層水份量（M_0）與BET模式M_0值之比較可知GAB模式所得之M_0值皆大於 BET之計算 M_0值。

團狀烏龍茶葉之數據約3.9~4.2%，而條狀烏龍之 GAB (M_0) 高達 5.0左右，此數據與茶葉所長期貯存要求含水率3－4%相比有偏高之趨勢，對實用價值而言， GAB (M_0) 值之意義不如 BET (M_0) 值，GAB模式所得之M_0值之可靠性值得懷疑。在玉米食品 (Corn meal) 與魚粉 (Fish flour) 的水活性測定中，其 GAB (M_0) 值均偏高於 BET (M_0) 值 (Labuza etal, 1985) ，與此研究之研究相符。

表 6. 團形烏龍茶葉GAB模式之估計係數

Table 6. The estimated parameters for GAB models of round type Oolong tea

	emp (°C)				
	5	15	25	35	45
M_0	4.11	3.886	4.0802	4.1206	4.1504
K	0.9836	0.9875	0.9737	0.9679	0.9549
C	10.084	11.209	6.9529	5.7654	5.8311
R^2	0.965	0.969	0.972	0.973	0.972

表 7. 條形烏龍茶葉GAB模式之估計係數

Table 7. The estimated parameters for GAB models of strip-type Oolong tea

	Temp (°C)				
	5	15	25	35	45
M_0	4.9951	4.8219	4.8973	4.8920	4.9564
K	0.9236	0.8958	0.8467	0.9170	0.8452
C	2.3614	1.9405	1.2761	1.1634	1.0999
R^2	0.992	0.993	0.964	0.962	0.983

GAB模式對於團形烏龍茶葉 ERH 適用性質由非線性迴歸結果所得之殘差分佈圖如圖7所示。在三種固定溫度條件下，其殘差分佈之趨勢均相似，在預測值大於12%12% (M. C.) 之範圍時，其誤差則大幅度增加，此模式對於烏龍茶葉性質之適用性不得高於70%。而且其參數與溫度無明顯相關性 (表6、7)。包含溫度項於各參數之關係式難以建立，且其於固定溫度下對反應值的解釋能力 (R^2值) 也未優於包含所有數據以進行迴歸分析的三參數ERH模式 (如修正Oswin公式) 。由此可知 GAB 模式對烏龍茶葉之適用性並不優良。

Van alen Berg 氏 (1984) 認爲GAB模式的優越性有(一)由BET模式修正改良而得，(二)可代表所

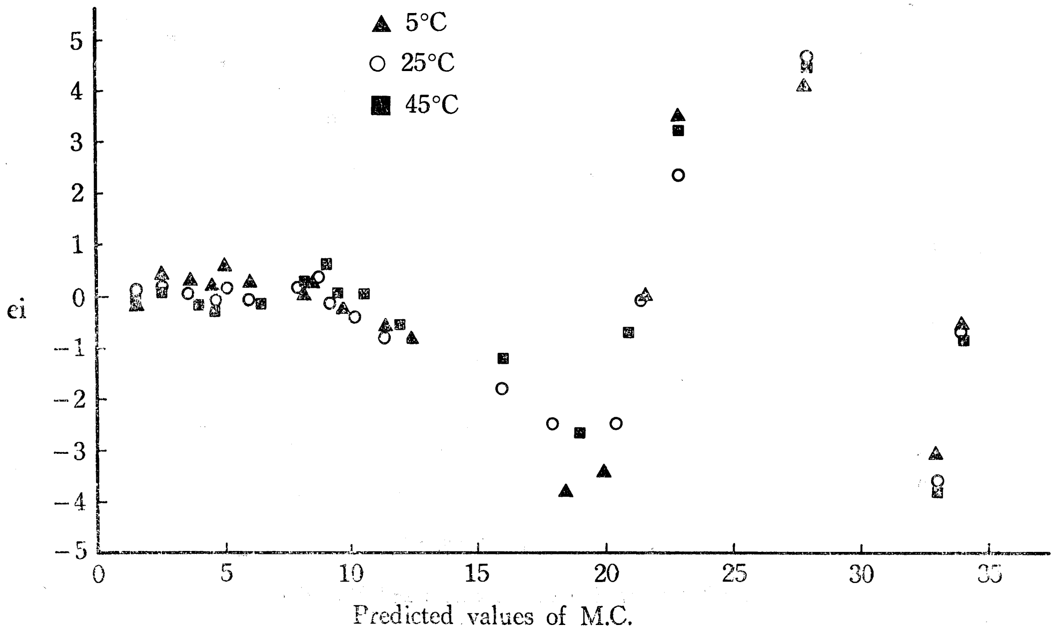


圖 7. 團形烏龍茶葉吸濕數據GAB模式之殘差圖

Figure 7. Residuals vs predicted values of GAB models for adsorption data of round-type oolong tea

有食品等溫水份線至90%RH 之範圍，(三)參數可建立溫度之關係式。由烏龍茶葉此項物項得知，這些特點並不存在，由此也證明無法以一個ERH模式適用於所有的食品或農產品ERH/EMC物性。

四、烏龍茶葉含水率之計算

由茶葉適用模式的研究中表達團形茶葉含水率與相對濕度和溫度之關係可以修正Oswin式代表：

$$M=(8.3424-0.02344\times T)*\left(\frac{RH}{1-RH}\right)^{0.566} \cdots\cdots (16)$$

由感應器測得之RH與T值利用（16）式計算所得之計算值（Mc）與標準含水率測定法所得之含水率（Ms）進行比較。有關的比較結果如下：

1.平衡時間20分鐘

以Rotronic感應器置於小塑膠容器內，設定平衡所需時間爲20分鐘，所測得之相對濕度和溫度經計算所得含水率與標準含水率之比較如圖 8 所示。

此技術所得的平均偏離差爲 0.294%，此意義代表以計算所得的含水率視爲眞實值時，其平均誤差低於0.3%，此已合乎實際之需要，殘差之分佈爲均勻性而無明顯趨勢。

以不含常數之線性迴歸，其結果列於表 8 。b_2之係數值爲0.978，此係數估計值與1.0值相異性之t值檢定如下：

$$t(b_2')=\frac{|0.978-1|}{0.01321}=1.67$$

在95%信賴區間條件下，此值不顯著，證明此種技術在統計上有其意義：

包含常數之線性迴歸其截矩值爲—0.312，斜率值爲1.0089。進行t檢定時，

$t(a_1')=1.31$

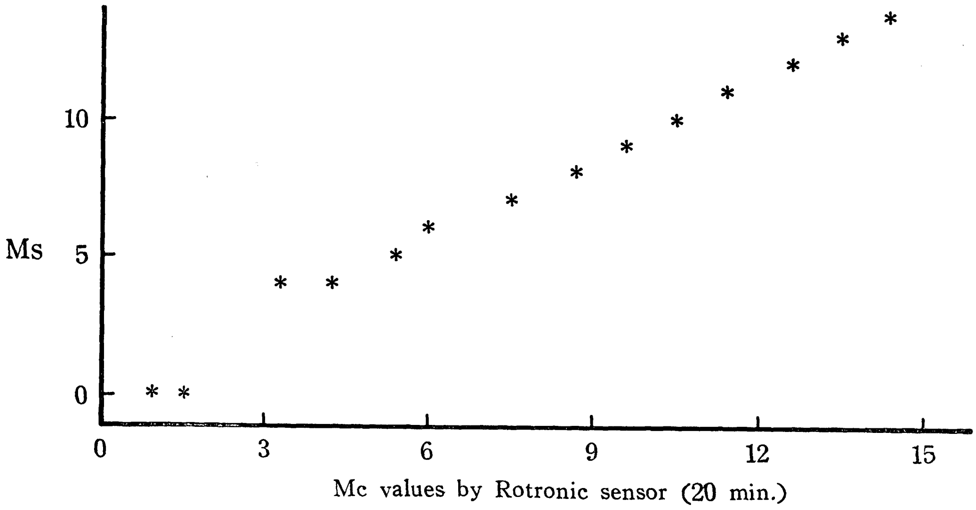


圖 8. 含水率量測値與標準値之比較

Figure 8. Comparsion of Mc values and Ms values

表 8. 兩種線性模式之迴歸係數和統計量

Table 8. Regression coefficient and statistics for two linear models

I. 20 min.			
1. Ms=b2*Mc			
Variable	Estimate	Std. Error	t value
b_2	.9779513	1.3209387E—02	74.03
	Degrees of freedom	= 13	
	Residual mean square	= .1918070	
	Root mean square	= .4379577	
2. Ms=a1+a2*Mc			
Variable	Estimate	Std. Error	t value
a_1	—.3124615	.2384887	—1.31
a_2	1.008928	2.6914250E—02	37.49
	Degrees of freedom	= 12	
	Residual mean square	= .1817870	
	Root mean square	= .4263648	
	R-squared	= .9915	
II. 15s min.			
1. M=b2*Mc			
Variable	Estimate	Std. Error	t value
b_2	1.005035	1.4614318E—02	68.77
	Degrees of freedom	= 27	
	Residual mean square	= .4430981	
	Root mean square	= .6656561	
2. Ms=a1+a2*Mc			
Variable	Estimate	Std. Error	t value
a_1	—.3930139	.2602278	—1.51
a_2	1.045279	3.0231610E—02	34.59
	Degrees of freedom	= 26	
	Residual mean square	= .4230291	
	Root mean square	= .6504068	
	R-squared	= .9787	

$$t(a_2')=\frac{|1.00893-1.0|}{0.0209}=0.33$$

在95%信賴區間條件下，a_1與0無顯著相異，a_2與 1.0亦無顯著相異。此結果證明此技術之可靠性。

2.平衡時間15分鐘

在此種時間條件下，含水率平均離差值為 0.535%，此即表示平衡時間影響了量測可信度，平衡時間愈長，誤差愈小。但以實用觀點而言，0.54%之誤差已可接受。

以不含常數項之迴歸結果計算 $t(b_2')$ 值為 0.345。以包括常數項之迴歸結果計算之 t 檢定值，$t(a_1')=1.51$, $t(b_1')=1.498$。以95%信賴區間之條件，這此 t 值均不顯著， 此即表示此種含水率之量測技術在驗證上十分合理。

以上三種方式之殘差圖均為平均分佈，無特定的模式誤差趨勢。

由此結果比較可知，以平衡相對濕度和溫度之測定以得到含水率時，其準確性可達實用之要求。

五、平衡相對濕度性質之應用

平衡相對濕度性質在農產品之實際應用如安定含水率，脆性維持，韌性維持，黴菌成長……等已有詳細之資料（Labuza, 1984，陳，1990）。在茶葉品質之應用方面，更有其應用之對象。

以茶葉含水率之測定為例，安定含水率之範圍為3－4％，其相應平衡相對濕度之範圍為30～35% 以相對濕度計置於茶葉樣本之中更能直接測定茶葉貯存條件是否適切。又如碎茶ERH物性研究結果中，在茶葉含水率大於8％以上時，再好的包裝技術或材料都無法長期保持茶葉品質（吳與阮，1978）。由圖4之資料，碎葉（Black tea）在8％之相應平衡相對濕度為 65%以上，在此相對濕度下微生物已開始活動，因此包裝之方法或材料不能改良品質。在圖4中可知的相對含水率為 8.4%（條狀烏龍）和 9.8%（團狀烏龍）。若利用含水率為品質指標，不同產品的茶葉有不同含水率之安全標準，但若以相對濕度為指標，所有的茶葉產品都有相同的標準值。在此可知，以相對濕度取代含水率為品質指標，其標準準一致性。且簡易，並有學術之意義。

結　論

綜合上述研究所得結論如下：

一、利用平衡相對濕度測定方法可適用於烏龍茶葉此項物性之測定，溫度對於等溫水份吸濕性的主要效導主要發生於70%RH以下的範圍。

二、茶葉ERH物性受到品種和製造方式等因子影響， 特定的茶葉產品必須執行其平衡相對濕度物性測定，避免利用其他產品之物性資料。

三、修正Oswin公式可適用於團形與條形兩種ERH物性性質。

四、烏龍茶葉的單層水份值，自 BET 模式計算之結果，約於3～4％之範圍。此種方式可應用於其他農產品。自GAB模式所得之單層水份值有偏高之趨向。

五、利用感應器可測定茶葉平衡相對濕度和溫度以計算其含水率，平均誤差在 0.5%左右，可達到實用性需求。以感應器直接測定平衡相對濕度值，在品質檢定上有其實用之意義。

參考文獻

吳振鐸、阮逸明，1978，碎型紅茶之包裝貯存研究及其應用。食品科學5(1)；63—77。

阮逸明、吳振鐸，1979，茶葉吸濕性及其水份安全含量簡易呈色檢定法之研究。食品科學6(1)：6－7。

陳加忠，1990，穀物平衡相對濕度性質貯存之應用，臺灣省農試所技術服務雙月刊1卷1期：4－7。

陳加忠、賴建洲、曹之祖，1990，稻穀平衡相對濕度性質之研究，中華農業研究排印中。

Brunauer, S., P. H., Emmett, and E. Teller, 1938, Adsorption of gases in multimolecular layers. J. Am. Chem. Soc. 60 : 309-319.

Bunn, J. M, and M. J. Buschermohle, 1986, Evaluating relative humidity sensors for measuring mois ture content of stored grains. The fifth internativnal drying symposium, Gambridge, M. A.

Chen, C, 1988, A study of equilibrium relative humidity for yellow-dent corn kernels, ph. D. thesis, University of Minnesota, St. Paul, MN.

Gough, M. C. 1976, Remote measuremant of moisture content in bulk grain using an air extraction technigue. JARE 21 : 217-219.

Hughes, F. J., J. L. Vaala, and R. B. Koch, 1965, Rapid measurement of moisture in flour by hygr ometry. In: Humidity and Moisture Vol : II pp. 133-136, Reinhold Publ, CO., N. Y.

Iglesias, H. and J. Chirife, 1982, Handbook of Food Isotherms, Academic Press, N. Y.

Jayaratnam, S. and D. Kirtisinghe, 1974, The effect of relative humidity on the storage life of made tea, Q. 44(4) : 170-172.

Labuza, T. P. 1984, Moisture Sorption: Practical Aspects of Isotherm, Measurement and Use, AACC Press, St, Paul, M. N.

Labuza, T. P., A. Kaanane, and J. Y. Chan, 1985, Effect of temperature on the moisture sorption Iso therms and water activity shift of two dehydrated foods. J. of Food Science , 50 : 385-391.

Myers, R. H. 1986, Classical and Modern Regression with Applicarion, PWS and Kent Publ. CO. M. A.

Teng, P. S. and R. E. Gaunt, 1980. Modelling systems of disease and yield loss in cereals, Agricultar al system 6 : 131-154.

Teng, P. S. 1985, Construction of predictive models: II Forcasting crop losses, Advances in Plant Pa thology Vol3, Chap8, pp. 179-204, Academic Press Inc, Loudon.

Van den Berg, C. 1984, Description of water activity of foods for engineering purposes by means of the G. A. B. models of sorption. In: "Engineering and Foods", Vol. I. Makenna, B. M. (eds.) p. 311-322 Elsevier Applies Science Paul. London and N. Y.

Van den Berg, C. 1985, Development of B. E. T.-like models for sorption of water on foods, theory and relevance. In: "Properties of water in Foods". D. Simatos and J. L. Multon (eds.). p. 119-131 M. Njhoff Publ. Netherlands.

Wolf, W. Speiss, Wel and G. Jung, 1973, Water vapour sorption isotherms of some foods, LibensWiss and Tech. 6(3) : 94-96.

Yoshitomi, Hitoshi, 1985, Equilibrium moisture content of tea leaves and stems for tea manufactore, Report of Tea study, V61 : 26-35. In Japanese.

Young, J. H. and G. L. Nelson, 1967, Research of hysteresis between adsorption and desorption isot herms of wheat. Trans of ASAE 10(3) : 756-761.

Young, J. H. 1983, Moisture. In: Instrumention and Measurement for Environmental Sciences. Mitch ell, B. W. (eds.) Chap 7. ASA E, St. Joseph, M. I.

A Study of the Adsorption Isothern of Oolong tea and in Application in Maintaining Tea Quality[1]

C. C. Chen, C. C. Lai and C. T. Tsao[2]

Summary

The equilibrium relative humidity properties of the adsorption isotherms for two types of Oolong tea were measured in this study. The results indicated that electronic RH sensor can serve as good device on ERH measurement. The main effect of temp erature shirt on isotherm were found below the range of 50%RH. The Modified-Oswin equation was the adequate model for two types of Oolong tea. The critical M. C. value for maintaining quality of Oolong tea was 3%—4%. The Mo values calculated by GAB model was signficantly higher than those of BET model. The moisture content of Oolong tea could be calculated by the measured values of ERH and temperature. The average deviation of this technique is nearly 0.5%.

Key words : Oolong tea, Adsorption isotherm, Monolayer value, ERH model

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